SPACE WEATHER FOR EMERGENCY COMMUNICATORS

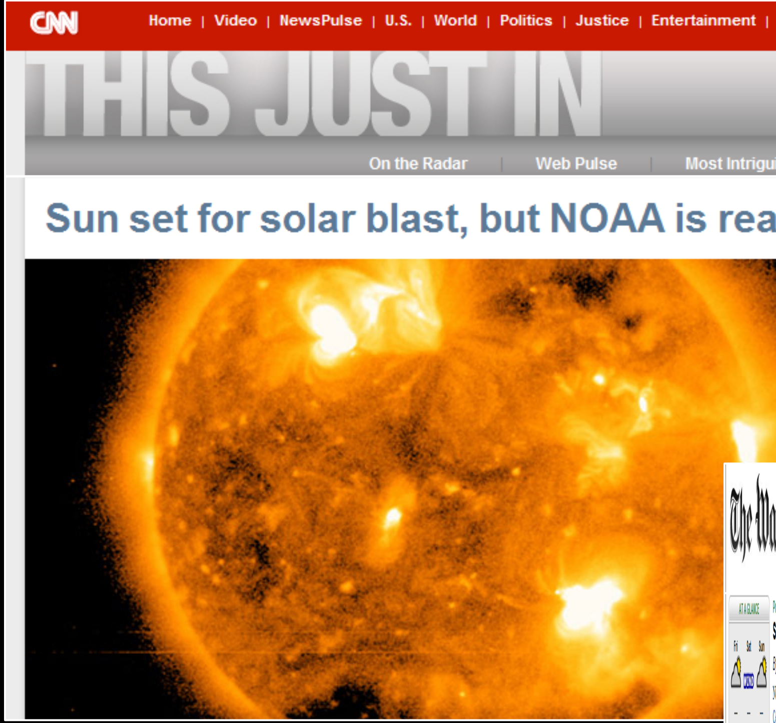
Rob Steenburgh, KA8JBY

NOAA Space Weather Prediction Center, Boulder, CO

Outline

- Solar Cycle 24 is underway
- Ionosphere
- Propagation
- Space Weather
- Situational Awareness
- Scenario

Feb 16-17, 2011


CNN
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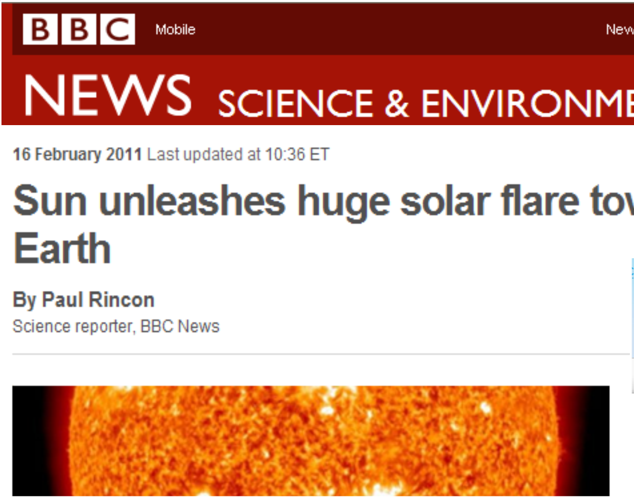
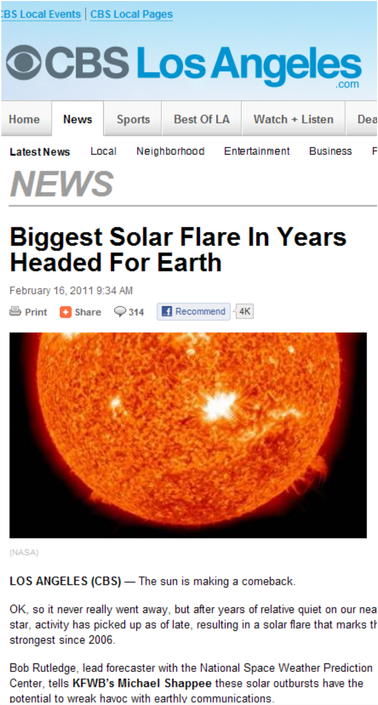
Sun set for solar blast, but NOAA is read



16 February 2011 Last updated at 10:36 ET

Sun unleashes huge solar flare towards Earth

By Paul Rincon
Science reporter, BBC News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Biggest Solar Flare In Years Headed For Earth

February 16, 2011 9:34 AM

(NASA)

LOS ANGELES (CBS) — The sun is making a comeback.

OK, so it never really went away, but after years of relative quiet on our nea
star, activity has picked up as of late, resulting in a solar flare that marks th
strongest since 2006.

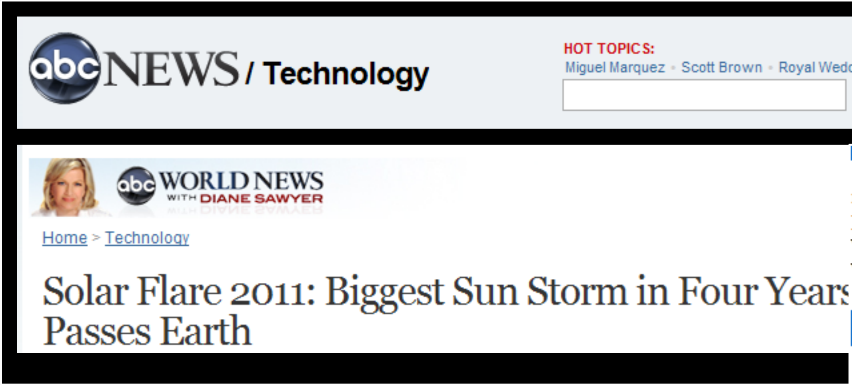
Bob Rutledge, lead forecaster with the National Space Weather Prediction Center, tells **KFWB's Michael Shappee** these solar outbursts have the potential to wreak havoc with earthly communications.

Posted at 9:40 AM ET, 02/17/2011

Solar Flare 2011: Aurora alert

By Steve Tracton

NOAA's Space Weather Prediction Center (SWPC) (part of NOAA's National Weather Service, NWS), has issued an alert for an increase in solar activity to moderate levels with


abc NEWS / Technology
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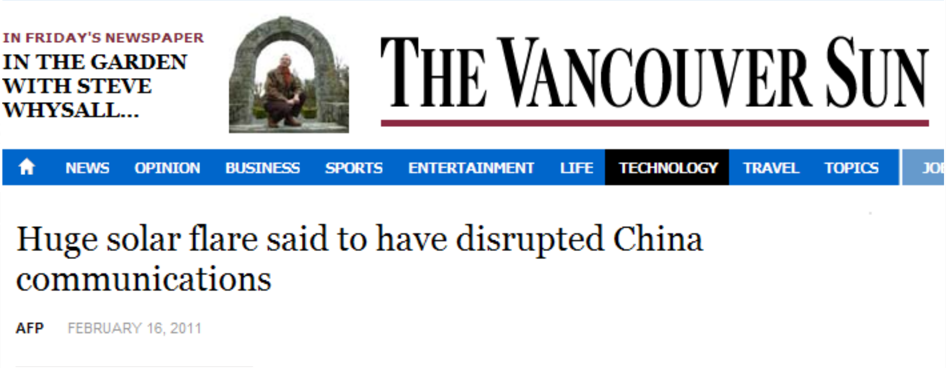
Solar Flare 2011: Biggest Sun Storm in Four Years Passes Earth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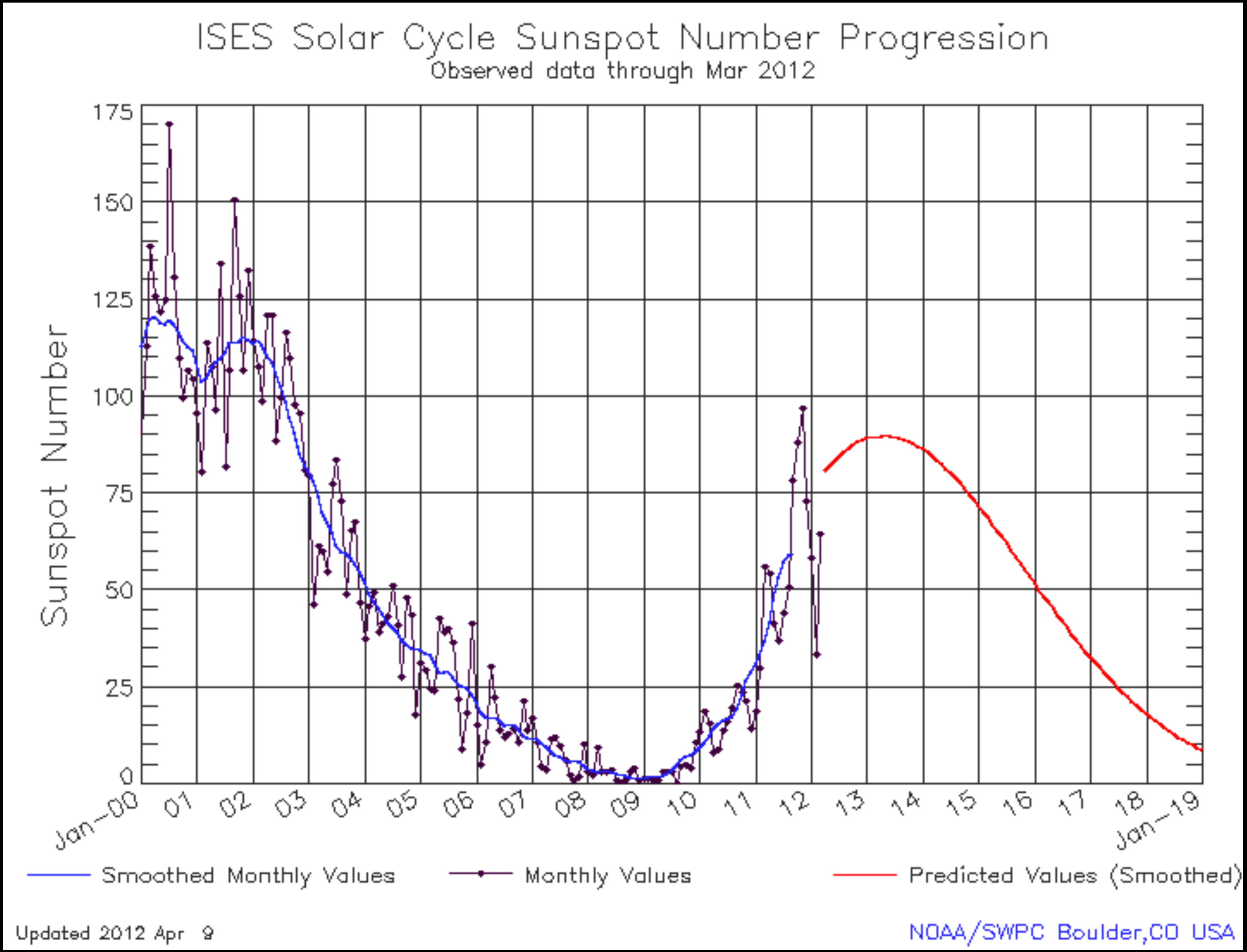
Huge solar flare said to have disrupted China communications

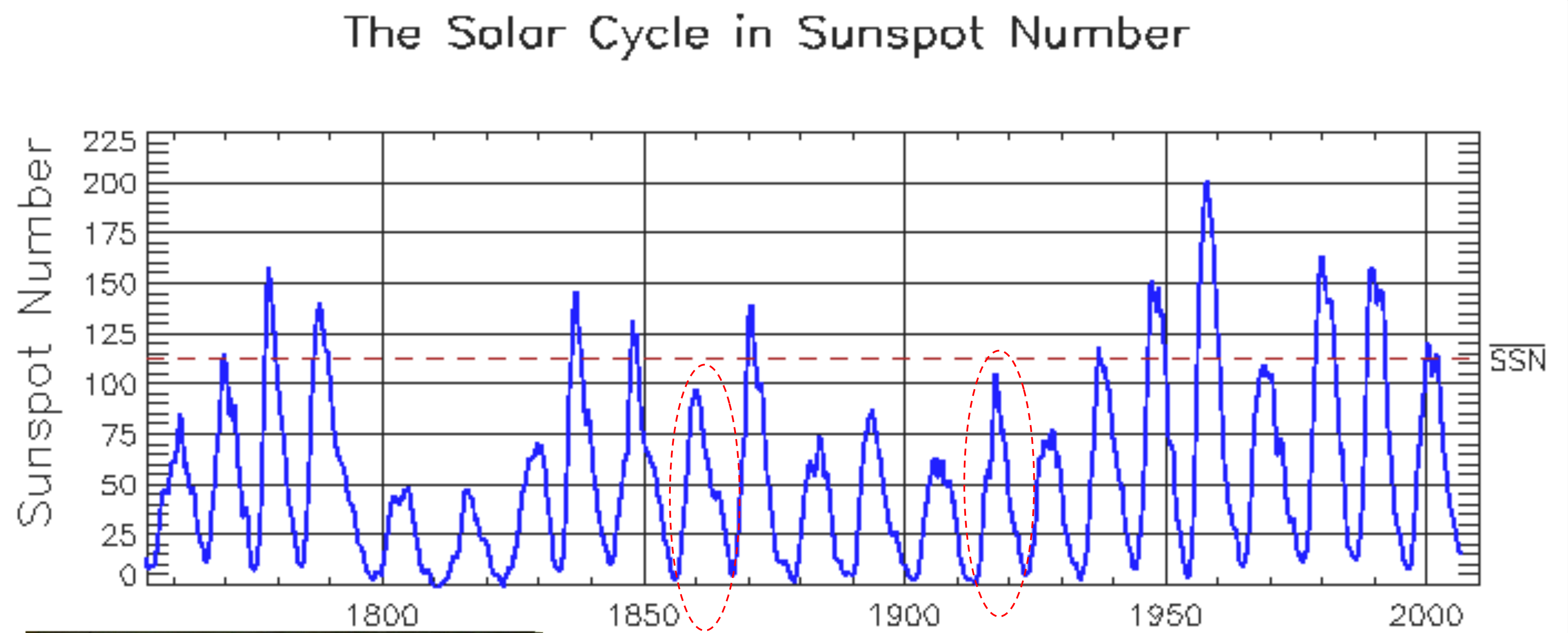
AFP FEBRUARY 16, 2011

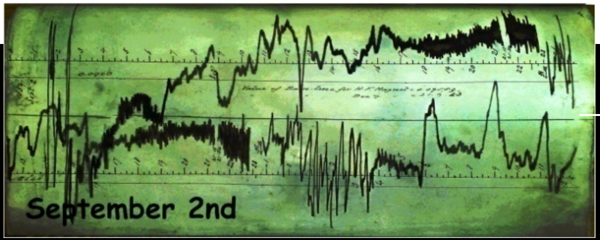
Cycle 24 is Underway



Don’t be fooled…

The largest recorded geomagnetic storm took place during a relatively modest solar cycle.

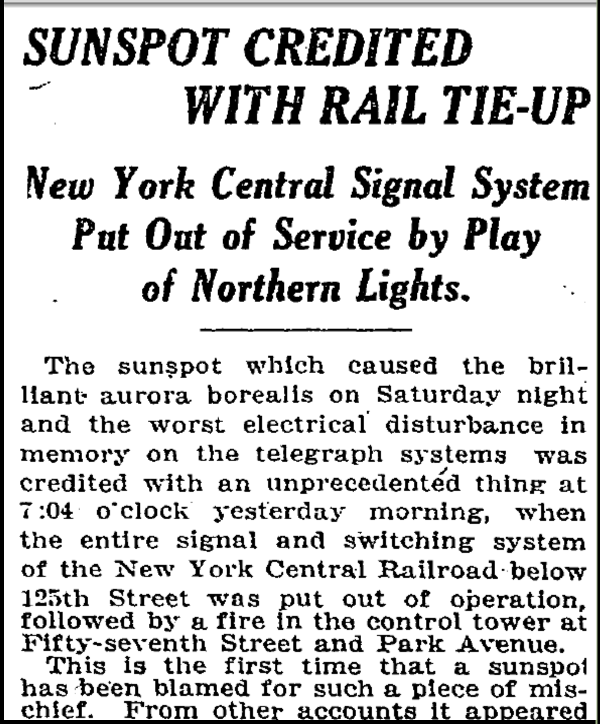




1859 Storm

1921 Storm

May 1921 Geomagnetic Storm



SUNSPOT CREDITED WITH RAIL TIE-UP

New York Central Signal System Put Out of Service by Play of Northern Lights.

The sunspot which caused the brilliant aurora borealis on Saturday night and the worst electrical disturbance in memory on the telegraph systems was credited with an unprecedented thing at 7:04 o'clock yesterday morning, when the entire signal and switching system of the New York Central Railroad below 125th Street was put out of operation, followed by a fire in the control tower at Fifty-seventh Street and Park Avenue.

This is the first time that a sunspot has been blamed for such a piece of mischief. From other accounts it appeared

The New York Times
Published: May 16, 1921
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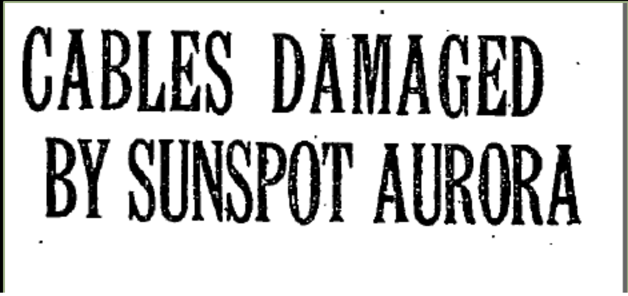
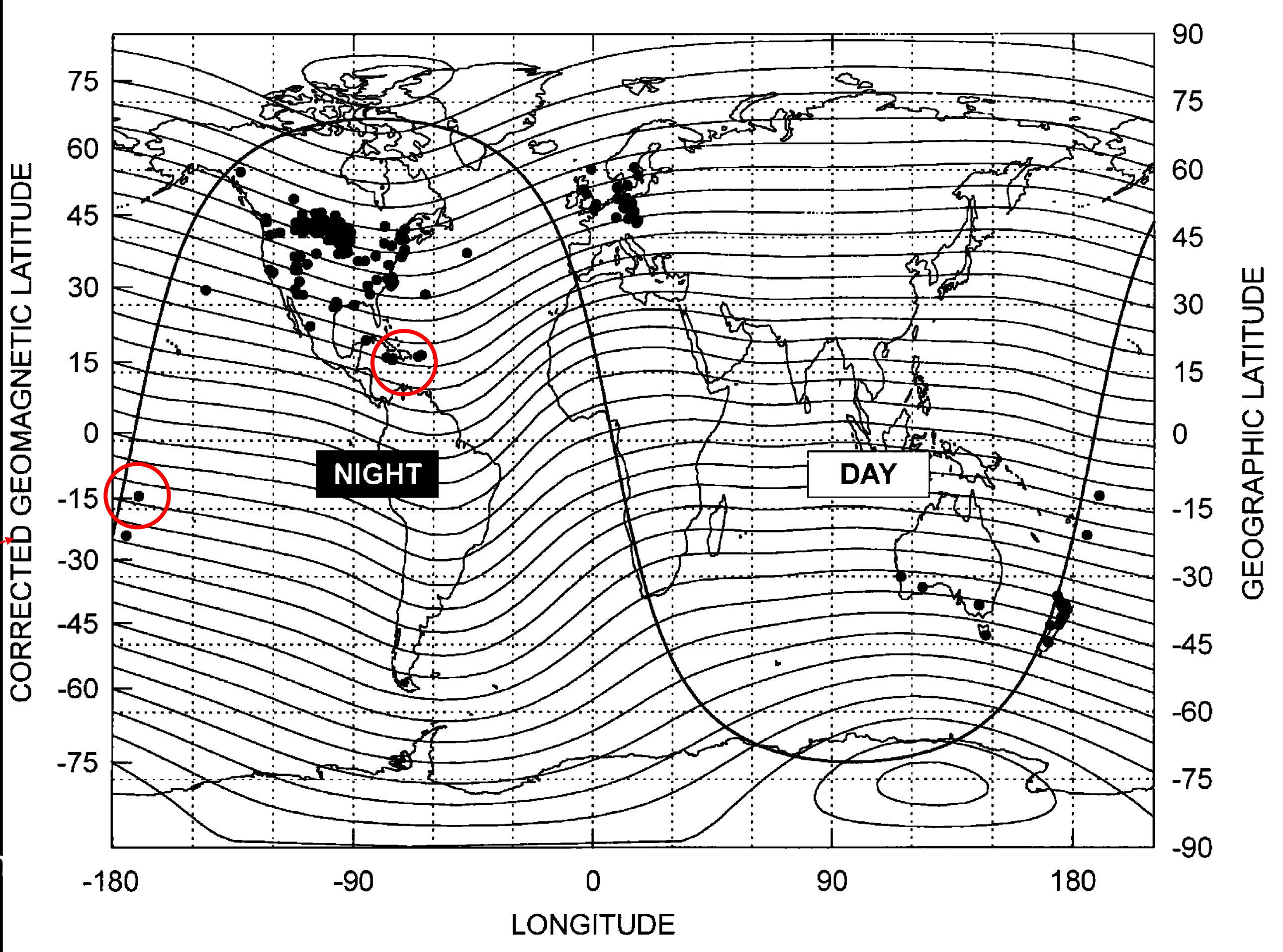


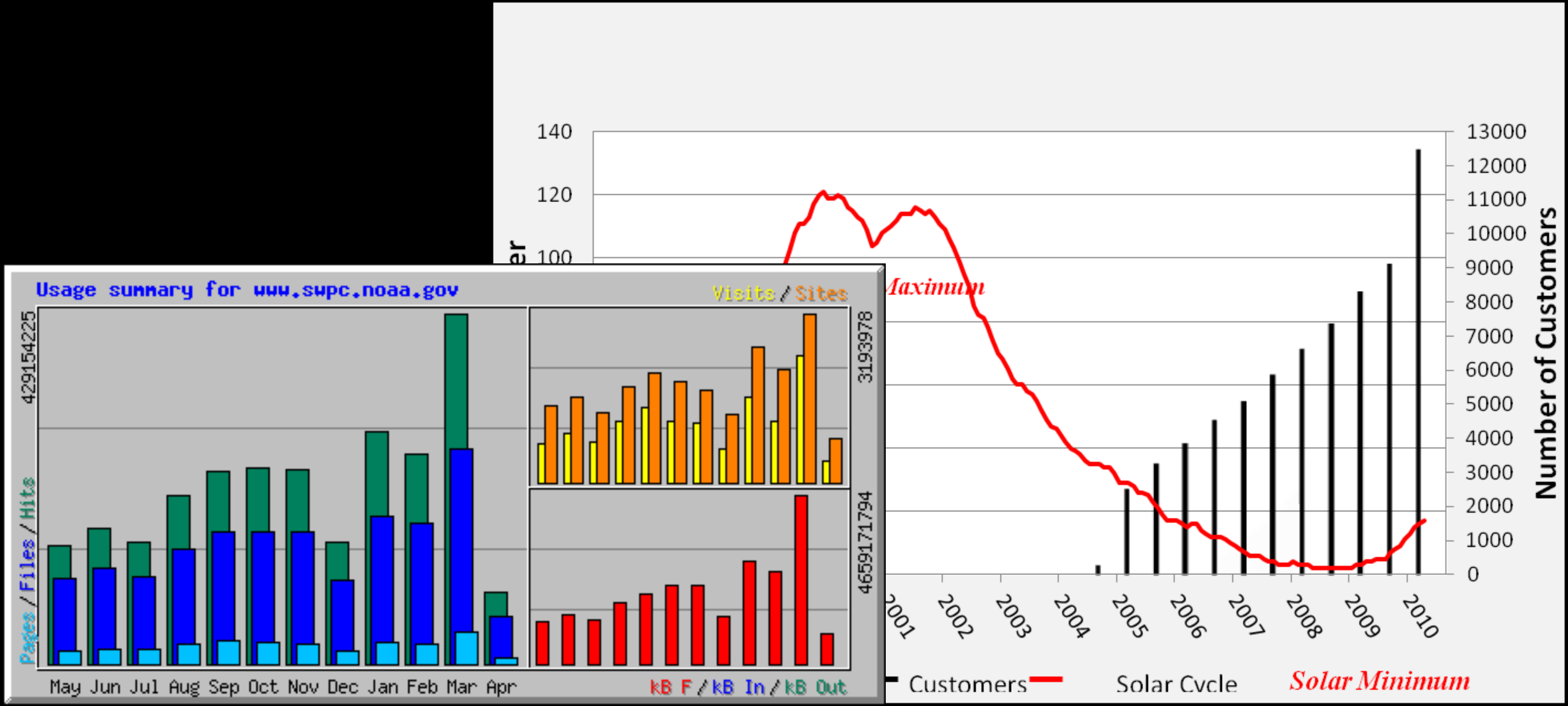
CABLES DAMAGED BY SUNSPOT AURORA



Apia, Samoa, 13 degrees south

Locations for which aurora were reported on 14–15 May 1921 – Silverman, *et al.*

So who cares?



- SES Satellite
- White House Communications
- Washington St. Dept of Transportation
- Inmarsat
- L-3 Communications
- Caterpillar, Inc. John Deere
- FEMA
- Motorola
- Major Airlines – UAL, AA, CO, Delta
- Boeing
- British Petroleum America
- United Launch Alliance
- FAA
- Bonneville Power Administration
- Salem and Hope Creek Nuclear Stations

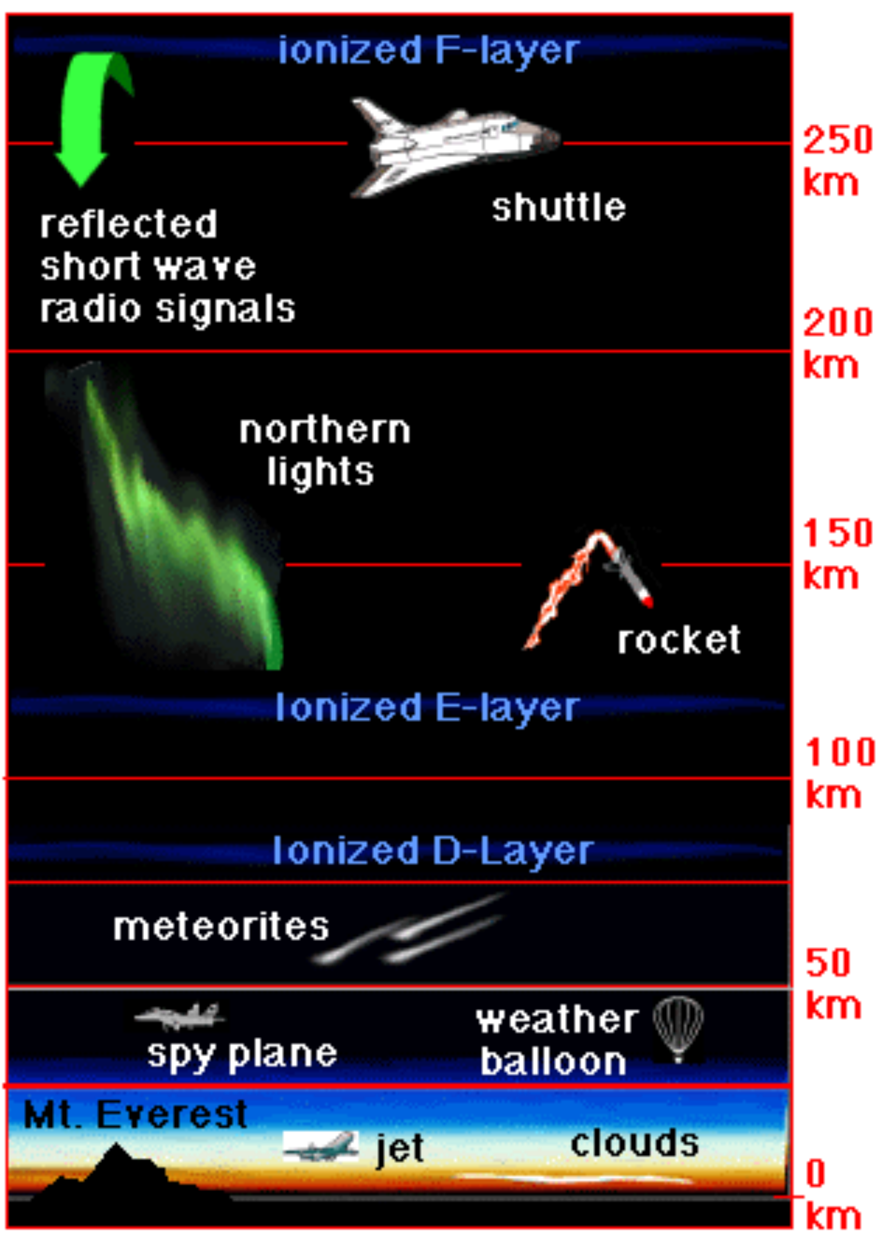
www.swpc.noaa.gov/alerts/index.html

The Ionosphere

The Ionosphere

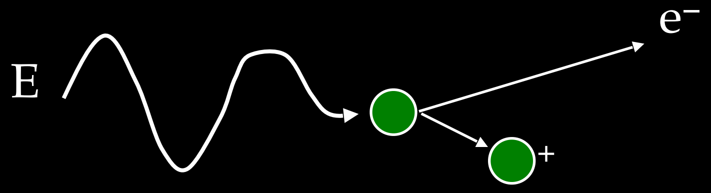
Region of the Earth’s atmosphere in which the plasma density is high enough to affect radio wave propagation (z > 50 km in daytime and z > 100 km at night), while neutral atmosphere still dense enough to influence plasma dynamics and photochemistry

Ionization of neutral atmospheric species caused primarily by incident solar radiation



The Ionosphere: Formation

- Radiation of sufficient energy hits atmosphere and ionizes neutral species
  - Solar x-ray and extreme ultraviolet (EUV) photons
  - Particle precipitation at high latitudes



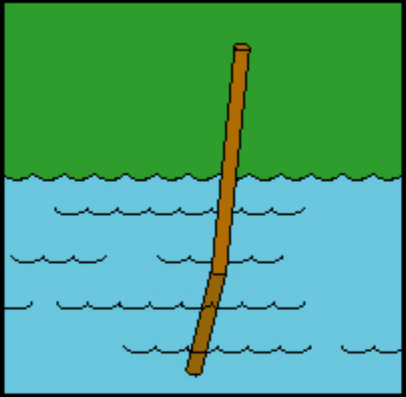
- Penetration of radiation into atmosphere depends on initial energy and available absorbers
  - Begins definition of distinct ionospheric layers

Ionization Threshold

	eV	nm
N_2	15.58	79.58
O_2	12.06	102.8
O	13.62	91.03
NO	9.264	133.8

Propagation

Radio Wave Propagation: Index of Refraction



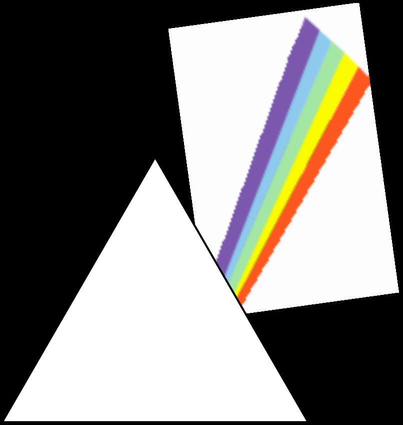
Defined as $n \equiv c/v_{phase}$

Light is bent at interface between different values of n

In a vacuum $n = 1$

Glass or water $n > 1$

- Also depends on wavelength
- Prism, lens coatings

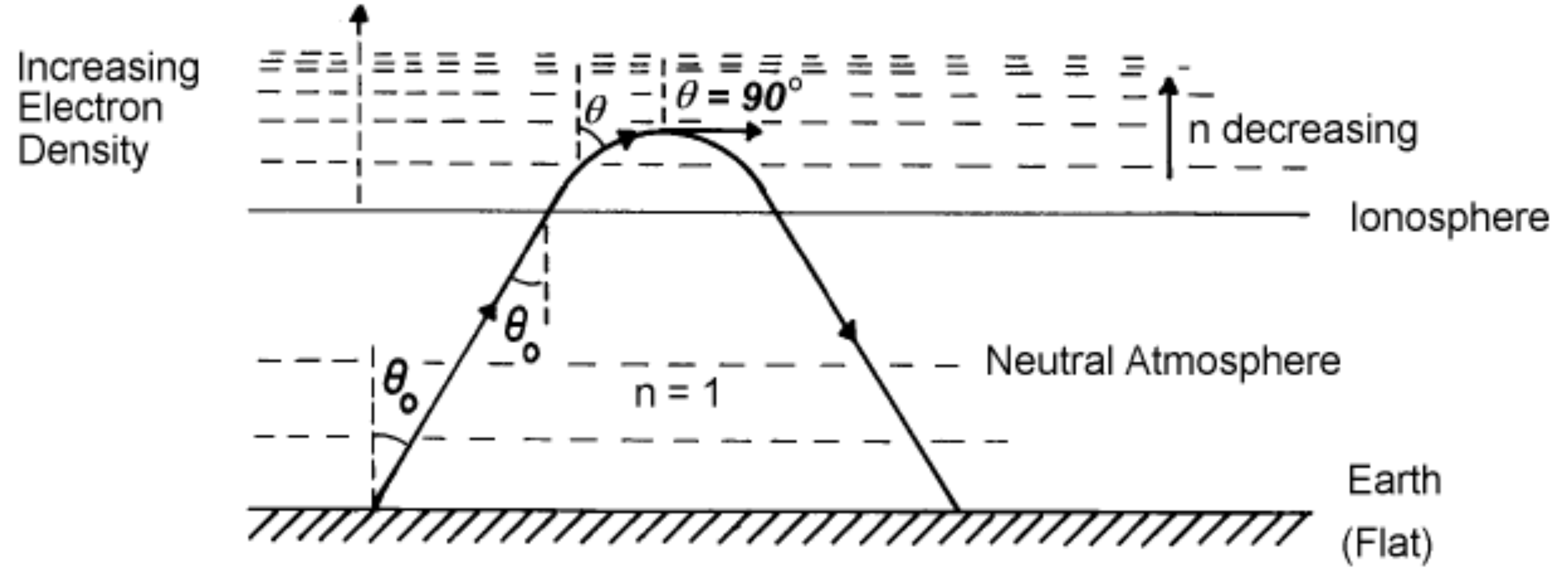


In a plasma

$$n = \sqrt{1 - \frac{f_p^2}{f^2}}$$

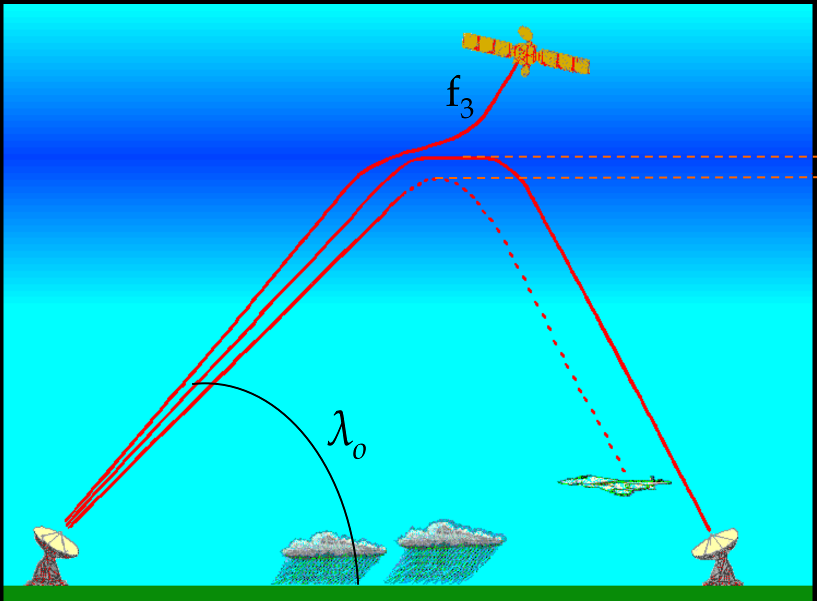
$$f_p(kHz) \cong 9 \cdot \sqrt{N_e(cm^{-3})}$$

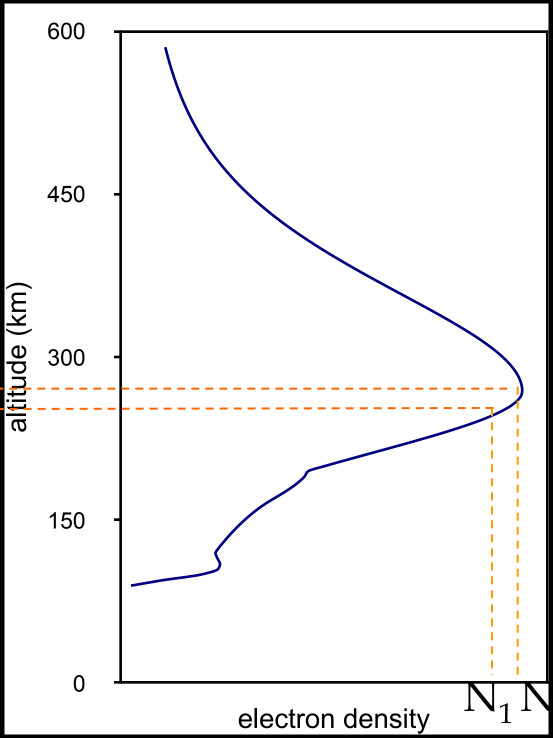
Radio Wave Propagation: Signal Refraction



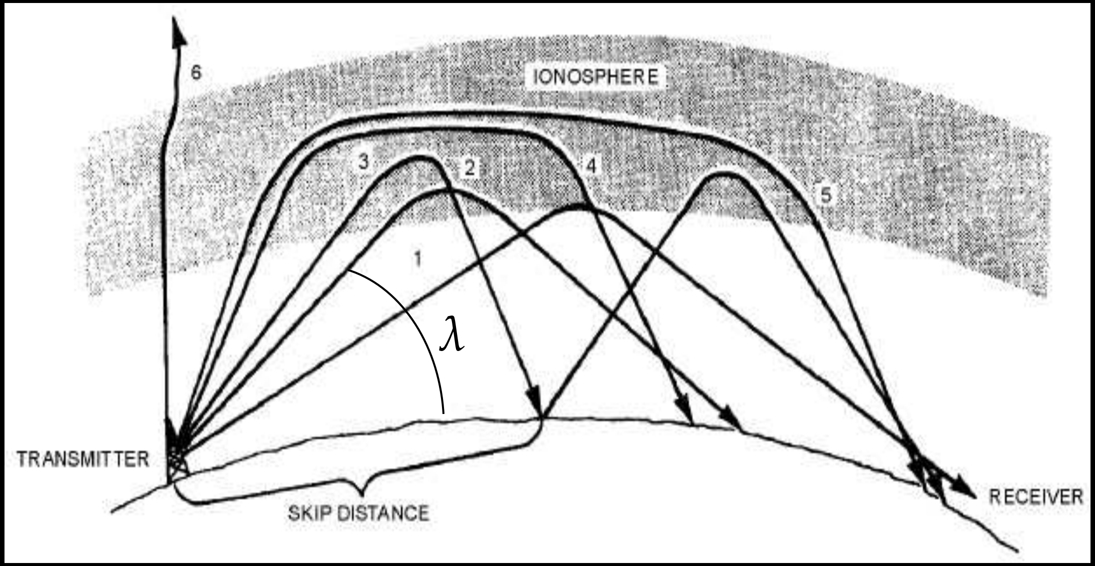
Radio Wave Propagation: Signal Refraction

$$N_e(\text{cm}^{-3}) \cong \frac{f^2(\text{kHz})\cos^2\theta_o}{80.6}$$





Radio Wave Propagation: Signal Refraction



$$N_e(\mathrm{cm}^{-3}) \cong \frac{f^2(\mathrm{kHz})\cos^2\theta_o}{80.6}$$

$$f_oF_2 < f_t < kf_oF_2\sec(\phi)$$

Radio Wave Propagation: Signal Refraction

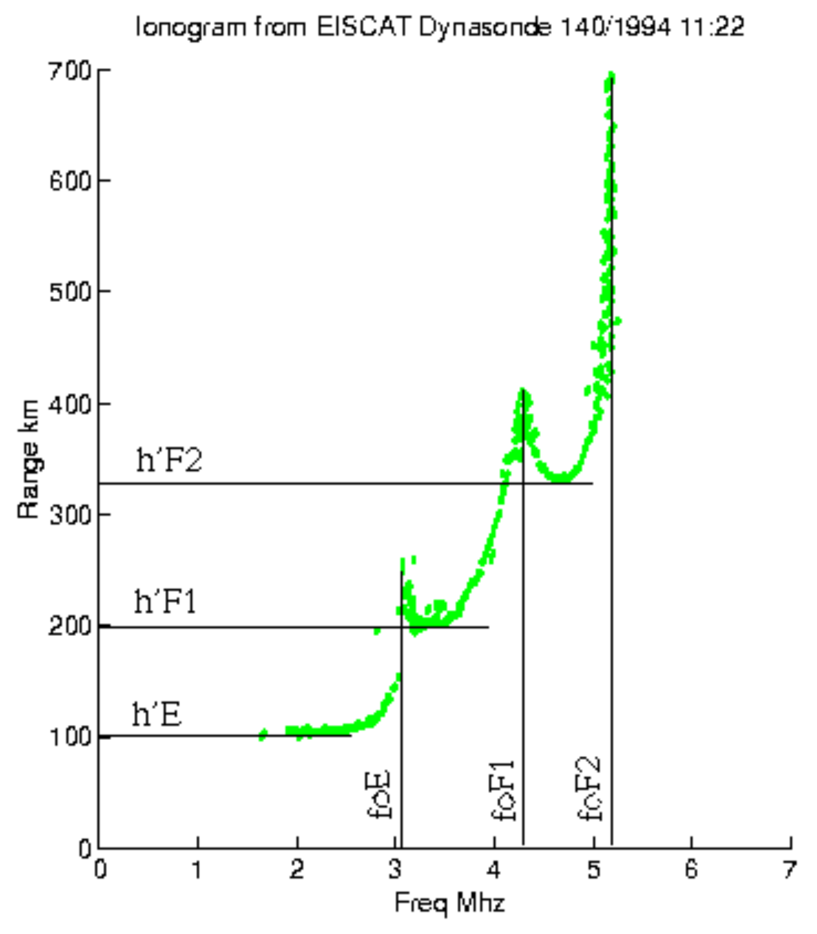
$$n = \sqrt{1 - \frac{f_p^2}{f^2}}$$

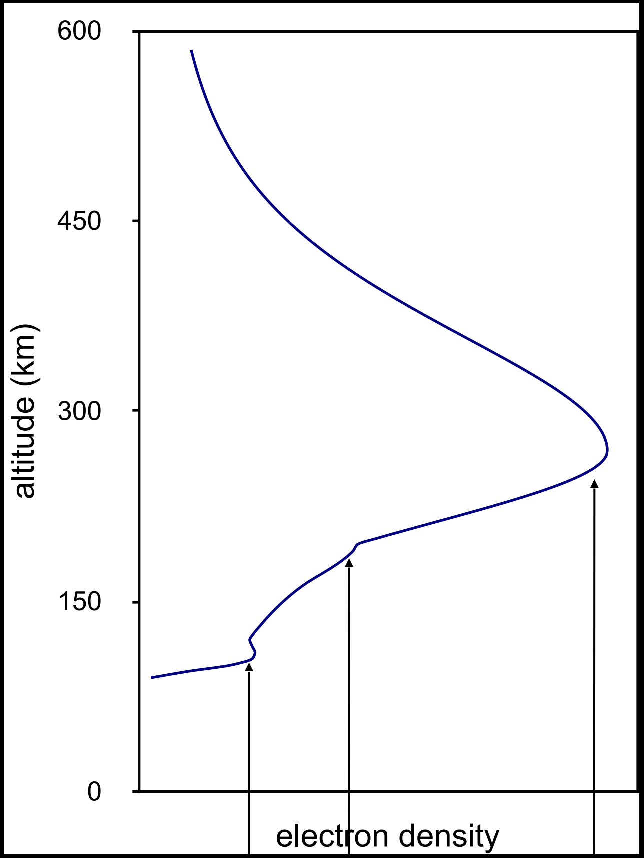
$$\boxed{f_p = f \cos\theta_o}$$

$$\boxed{N_e(\mathrm{cm}^{-3}) \cong \frac{f^2(\mathrm{kHz}) \cos^2\theta_o}{80.6}}$$

$$\boxed{f(\mathrm{kHz}) \cong 9 \sec\theta_o \sqrt{N_e(\mathrm{cm}^{-3})}}$$

Radio Wave Propagation: Vertical Propagation





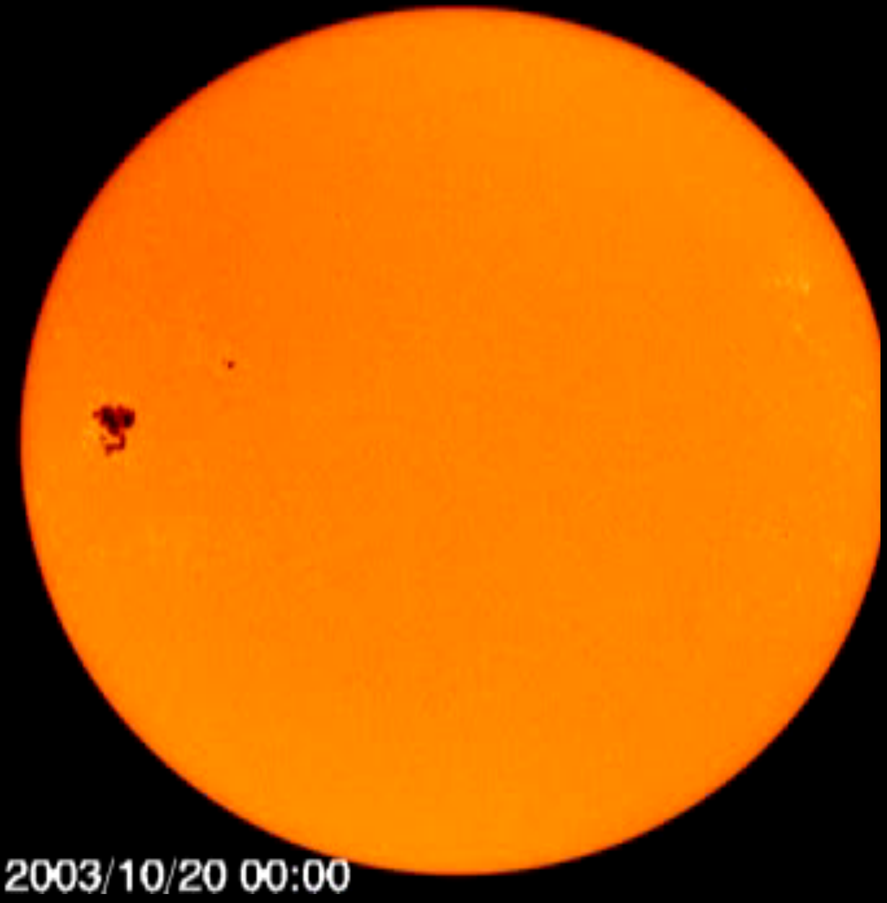
Radio Wave Propagation: Attenuation

$$\kappa \propto \frac{N\nu}{f^2}$$

Space Weather

Sunspots and the Solar Cycle

The Sun at Solar Maximum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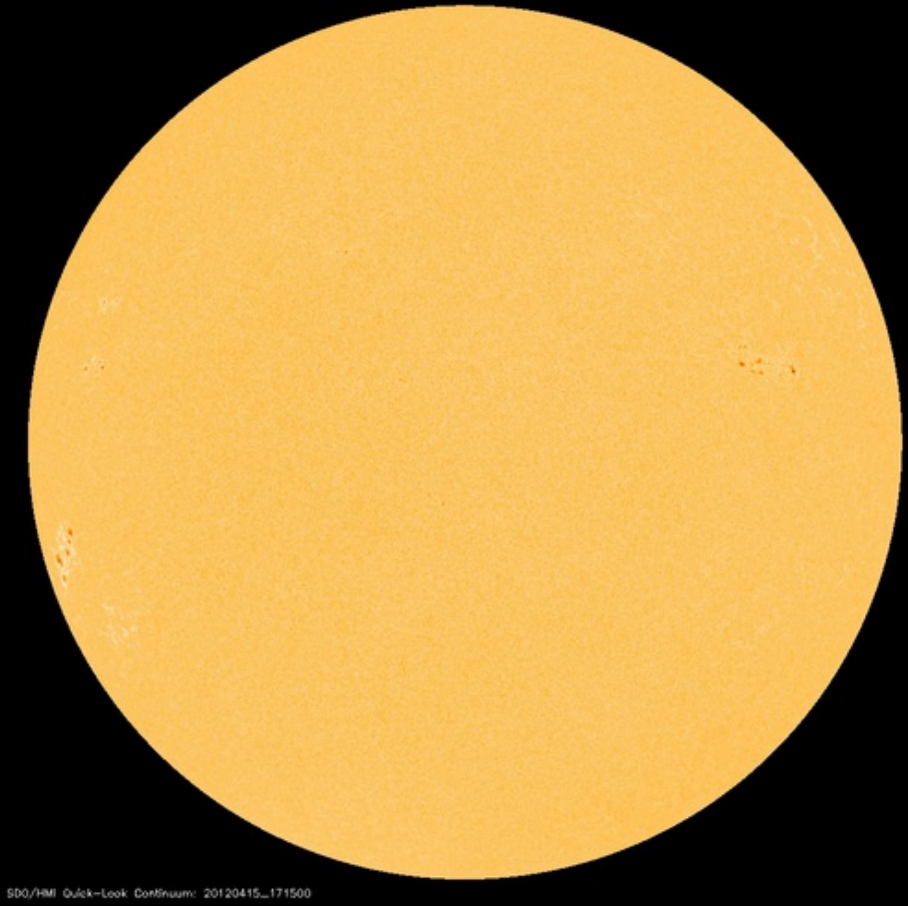
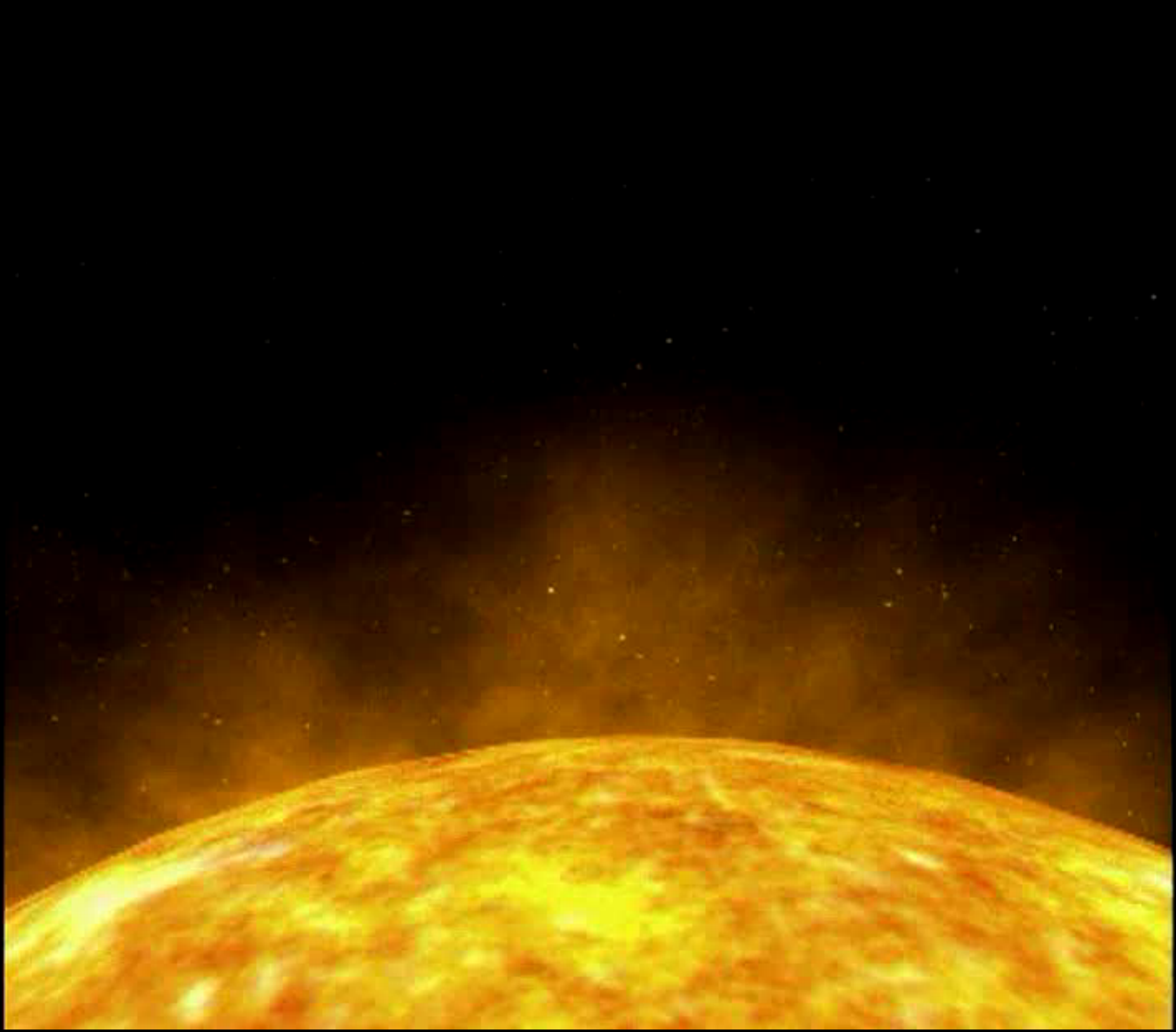
The Sun Today

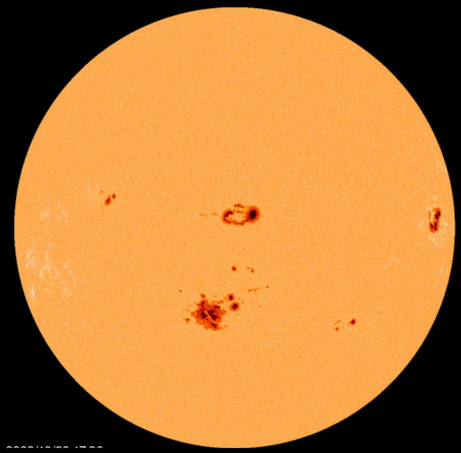

SDO/HMI Quick-Look Continuum: 20120415_171500

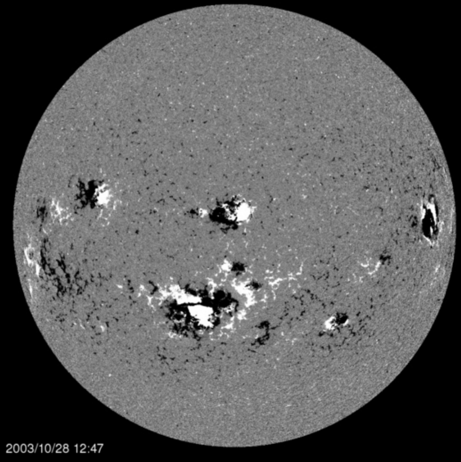
~27 day full rotation

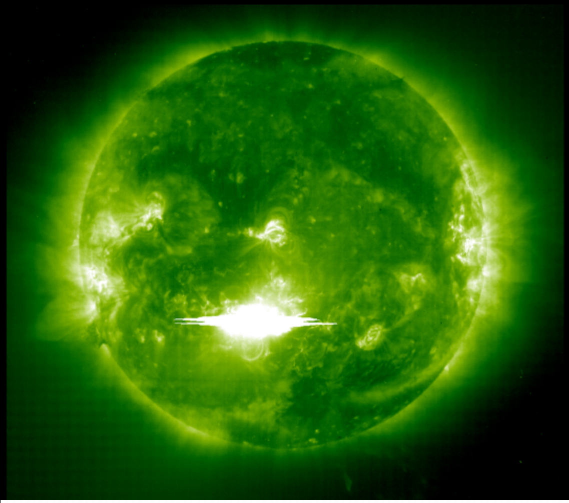
Ionospheric Phenomena

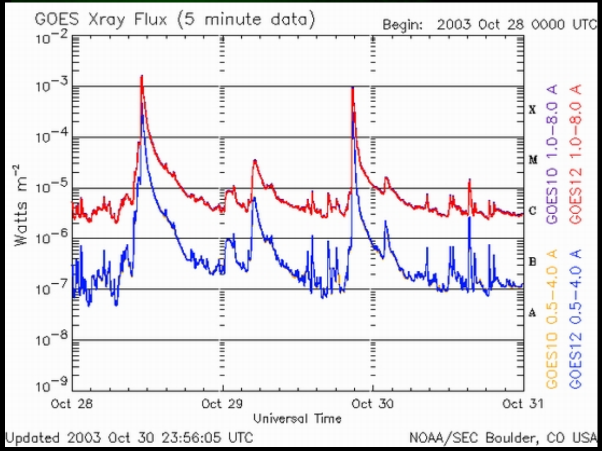
- Space weather storms can be roughly divided into three categories
    - **Flare effects;** due to increased photon flux during the flare
    - **Energetic particle effects;** due to arrival of MeV protons
    - **Geomagnetic storm effects;** due to magnetospheric changes following arrival of CME or CIR/HSS
- Each category affects the ionosphere

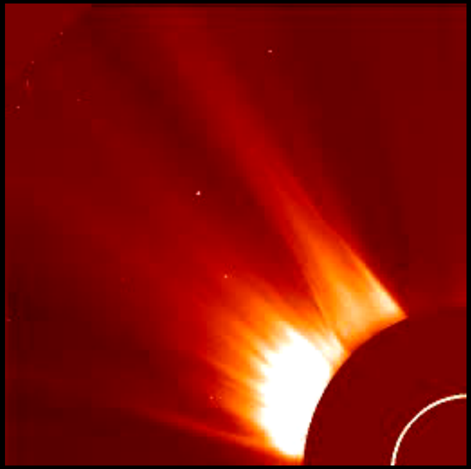


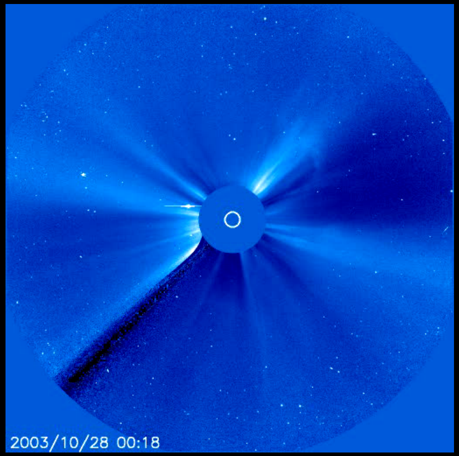



2003/10/28 12:47




GOES Xray Flux (5 minute data)
Begin: 2003 Oct 28 0000 UTC
Watts m^{-2}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
X
M
C
B
A
GOES10 1.0–8.0 A
GOES12 1.0–8.0 A
GOES10 0.5–4.0 A
GOES12 0.5–4.0 A
Oct 28
Oct 29
Oct 30
Oct 31
Universal Time
Updated 2003 Oct 30 23:56:05 UTC
NOAA/SEC Boulder, CO USA

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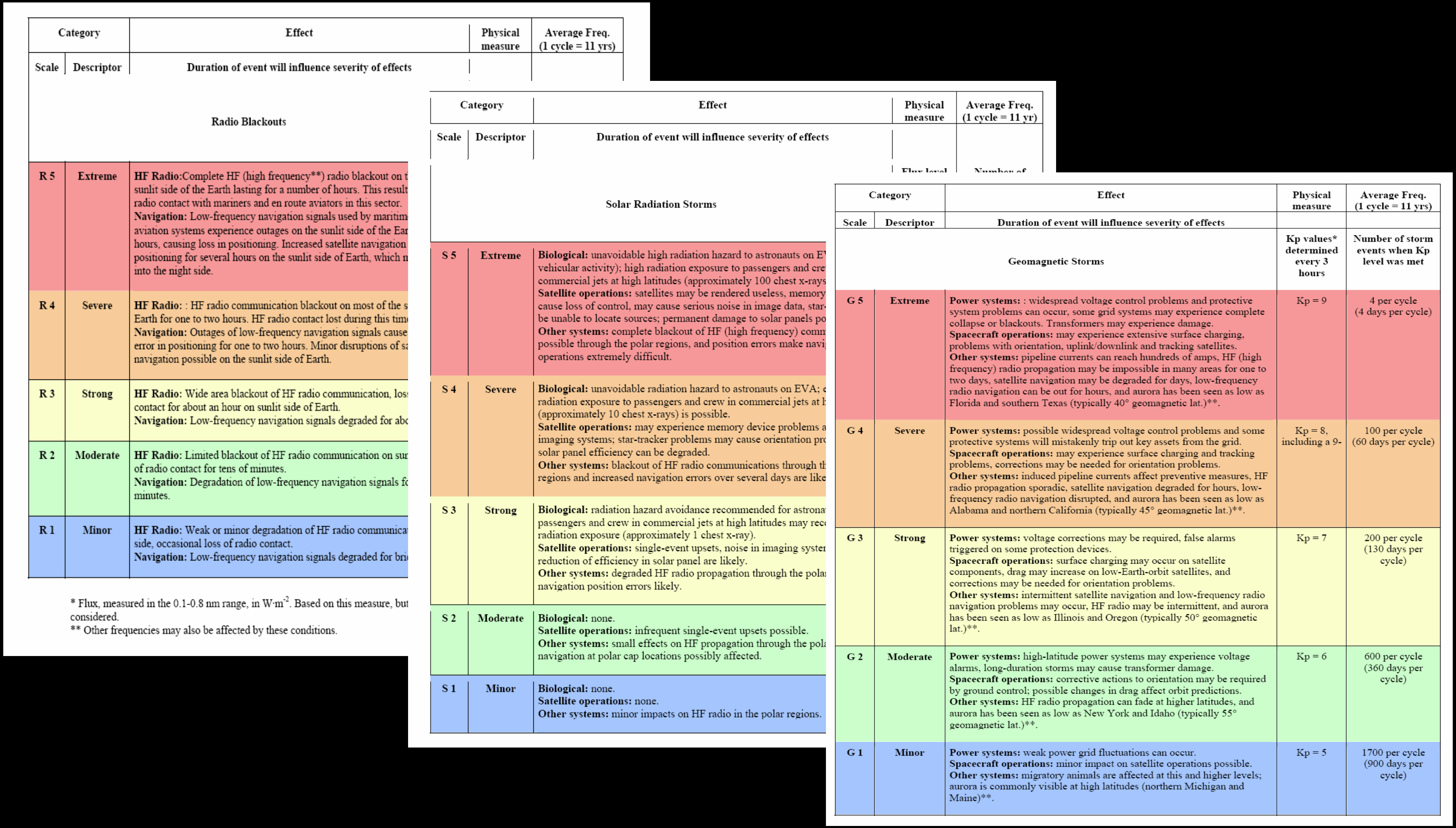
http://www.swpc.noaa.gov/NOAAscales/



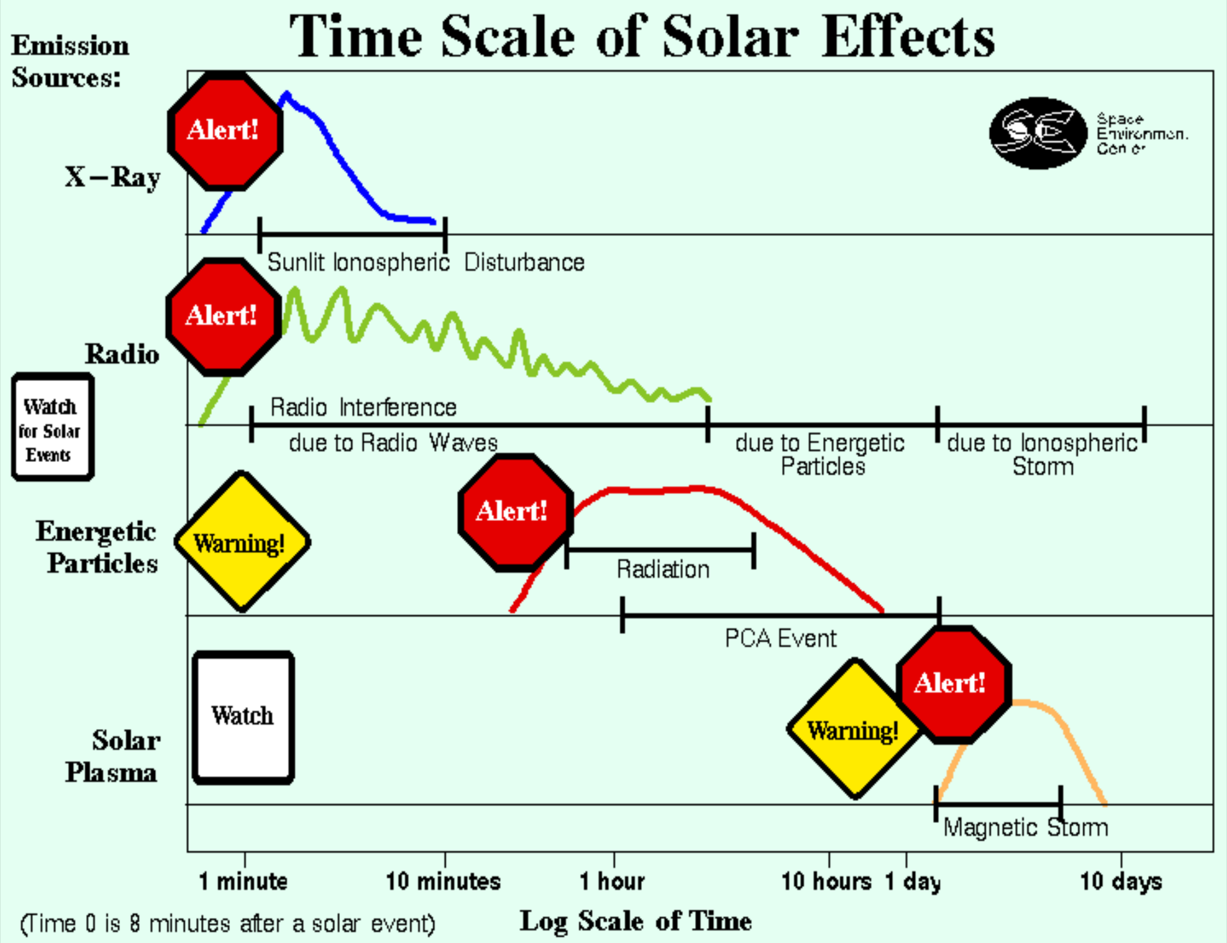
Category		Effect	Physical measure	Average Freq. (1 cycle = 11 yrs)
Scale	Descriptor	Duration of event will influence severity of effects		
		Radio Blackouts		
R 5	Extreme	**HF Radio:**Complete HF (high frequency**) radio blackout on t sunlit side of the Earth lasting for a number of hours. This result radio contact with mariners and en route aviators in this sector. **Navigation:** Low-frequency navigation signals used by maritim aviation systems experience outages on the sunlit side of the Ear hours, causing loss in positioning. Increased satellite navigation positioning for several hours on the sunlit side of Earth, which m into the night side.		
R 4	Severe	**HF Radio:** : HF radio communication blackout on most of the s Earth for one to two hours. HF radio contact lost during this tim **Navigation:** Outages of low-frequency navigation signals cause error in positioning for one to two hours. Minor disruptions of sa navigation possible on the sunlit side of Earth.		
R 3	Strong	**HF Radio:** Wide area blackout of HF radio communication, los contact for about an hour on sunlit side of Earth. **Navigation:** Low-frequency navigation signals degraded for abo		
R 2	Moderate	**HF Radio:** Limited blackout of HF radio communication on sur of radio contact for tens of minutes. **Navigation:** Degradation of low-frequency navigation signals fo minutes.		
R 1	Minor	**HF Radio:** Weak or minor degradation of HF radio communica side, occasional loss of radio contact. **Navigation:** Low-frequency navigation signals degraded for bri		

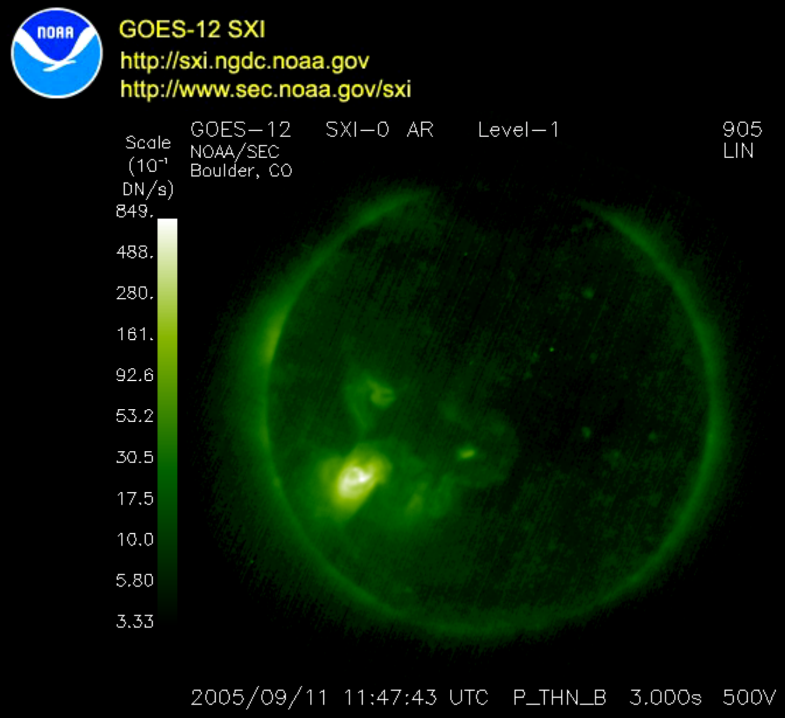
* Flux, measured in the 0.1-0.8 nm range, in W·m^{-2}. Based on this measure, but considered.
** Other frequencies may also be affected by these conditions.

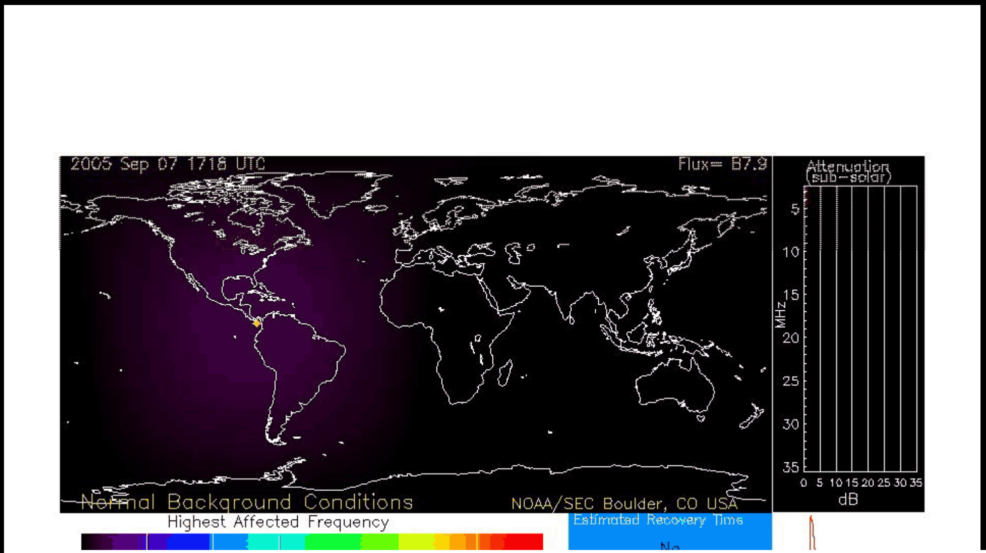
Category		Effect	Physical measure	Average Freq. (1 cycle = 11 yr)
Scale	Descriptor	Duration of event will influence severity of effects		
			Flux level	Number of
		Solar Radiation Storms		
S 5	Extreme	**Biological:** unavoidable high radiation hazard to astronauts on E vehicular activity); high radiation exposure to passengers and cre commercial jets at high latitudes (approximately 100 chest x-rays **Satellite operations:** satellites may be rendered useless, memory cause loss of control, may cause serious noise in image data, star- be unable to locate sources; permanent damage to solar panels po **Other systems:** complete blackout of HF (high frequency) comm possible through the polar regions, and position errors make navi operations extremely difficult.		
S 4	Severe	**Biological:** unavoidable radiation hazard to astronauts on EVA; radiation exposure to passengers and crew in commercial jets at (approximately 10 chest x-rays) is possible. **Satellite operations:** may experience memory device problems a imaging systems; star-tracker problems may cause orientation pr solar panel efficiency can be degraded. **Other systems:** blackout of HF radio communications through th regions and increased navigation errors over several days are like		
S 3	Strong	**Biological:** radiation hazard avoidance recommended for astrona passengers and crew in commercial jets at high latitudes may rec radiation exposure (approximately 1 chest x-ray). **Satellite operations:** single-event upsets, noise in imaging syste reduction of efficiency in solar panel are likely. **Other systems:** degraded HF radio propagation through the pola navigation position errors likely.		
S 2	Moderate	**Biological:** none. **Satellite operations:** infrequent single-event upsets possible. **Other systems:** small effects on HF propagation through the pol navigation at polar cap locations possibly affected.		
S 1	Minor	**Biological:** none. **Satellite operations:** none. **Other systems:** minor impacts on HF radio in the polar regions.		

Category		Effect	Physical measure	Average Freq. (1 cycle = 11 yrs)
Scale	Descriptor	Duration of event will influence severity of effects		
		Geomagnetic Storms	Kp values* determined every 3 hours	Number of storm events when Kp level was met
G 5	Extreme	**Power systems:** : widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. **Spacecraft operations:** may experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites. **Other systems:** pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.)**.	Kp = 9	4 per cycle (4 days per cycle)
G 4	Severe	**Power systems:** possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid. **Spacecraft operations:** may experience surface charging and tracking problems, corrections may be needed for orientation problems. **Other systems:** induced pipeline currents affect preventive measures, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen as low as Alabama and northern California (typically 45° geomagnetic lat.)**.	Kp = 8, including a 9-	100 per cycle (60 days per cycle)
G 3	Strong	**Power systems:** voltage corrections may be required, false alarms triggered on some protection devices. **Spacecraft operations:** surface charging may occur on satellite components, drag may increase on low-Earth-orbit satellites, and corrections may be needed for orientation problems. **Other systems:** intermittent satellite navigation and low-frequency radio navigation problems may occur, HF radio may be intermittent, and aurora has been seen as low as Illinois and Oregon (typically 50° geomagnetic lat.)**.	Kp = 7	200 per cycle (130 days per cycle)
G 2	Moderate	**Power systems:** high-latitude power systems may experience voltage alarms, long-duration storms may cause transformer damage. **Spacecraft operations:** corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. **Other systems:** HF radio propagation can fade at higher latitudes, and aurora has been seen as low as New York and Idaho (typically 55° geomagnetic lat.)**.	Kp = 6	600 per cycle (360 days per cycle)
G 1	Minor	**Power systems:** weak power grid fluctuations can occur. **Spacecraft operations:** minor impact on satellite operations possible. **Other systems:** migratory animals are affected at this and higher levels; aurora is commonly visible at high latitudes (northern Michigan and Maine)**.	Kp = 5	1700 per cycle (900 days per cycle)

Space Weather Time Scale







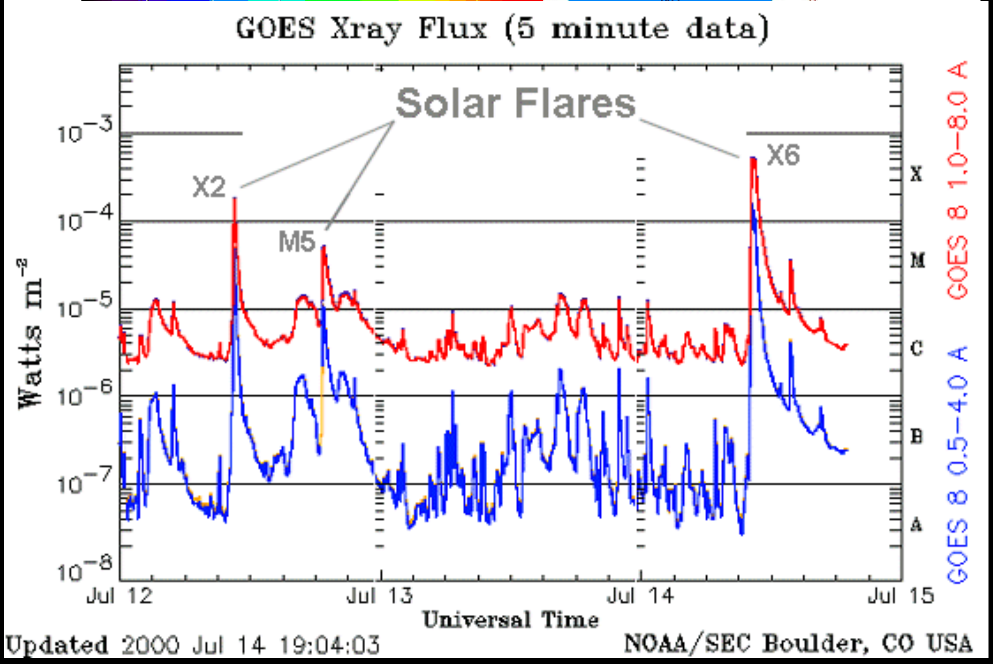
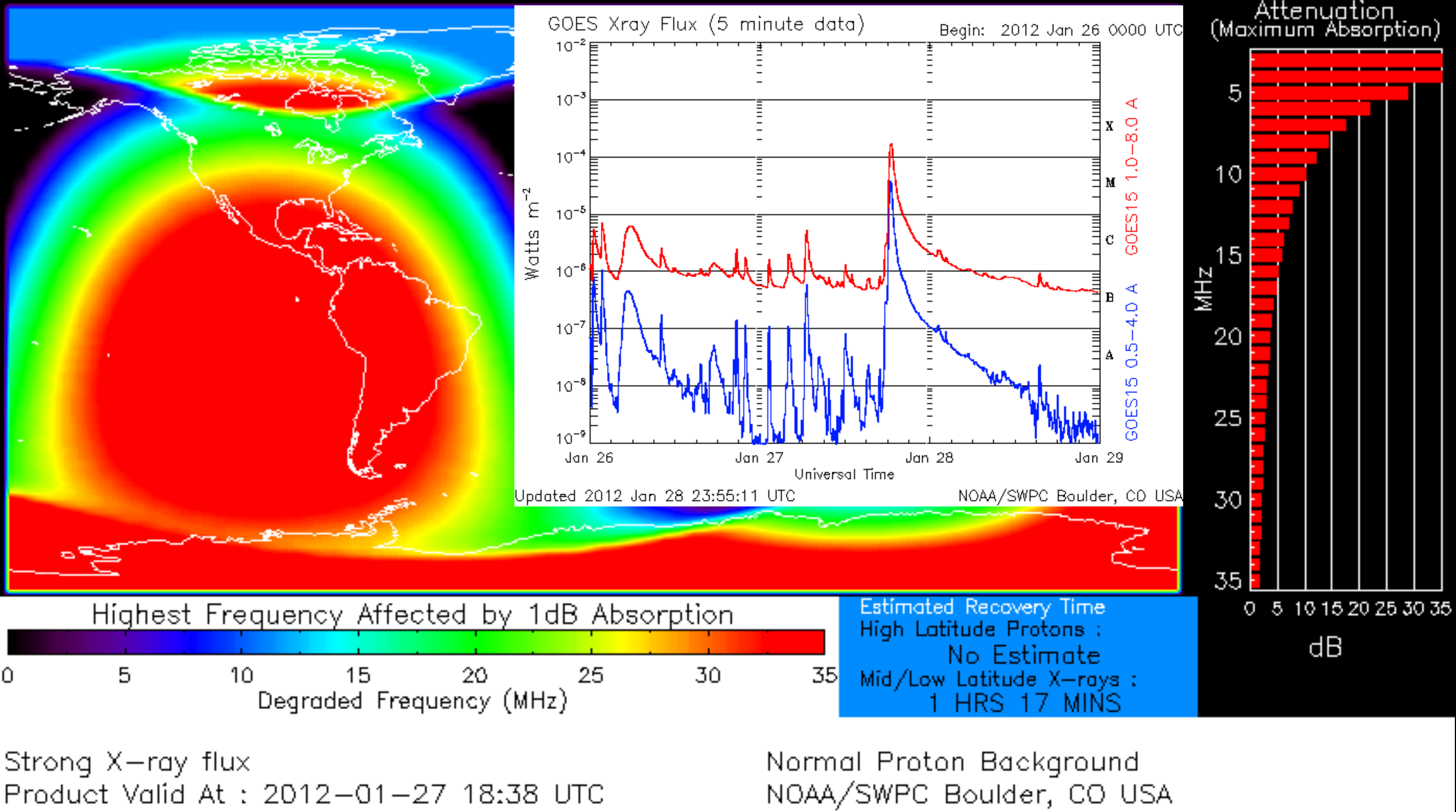


Image credit ESA/NASA SOHO

Sudden Ionospheric Disturbance (SID)

- Generic term encompassing a broad category of ionospheric effects all due to increased photon flux during solar flares
- All phenomenon occur within minutes of flare
- Duration determined by the flare (~ hour)
- **Affects sunlit side of the Earth**
- Enhancement of solar x-ray and extreme ultraviolet radiation leads to additional ionization
  - D region shows large % increase in electron density
- Shortwave Fadeout (SWF)
  - Absorption of HF frequencies

27 Jan 2012 X1-flare

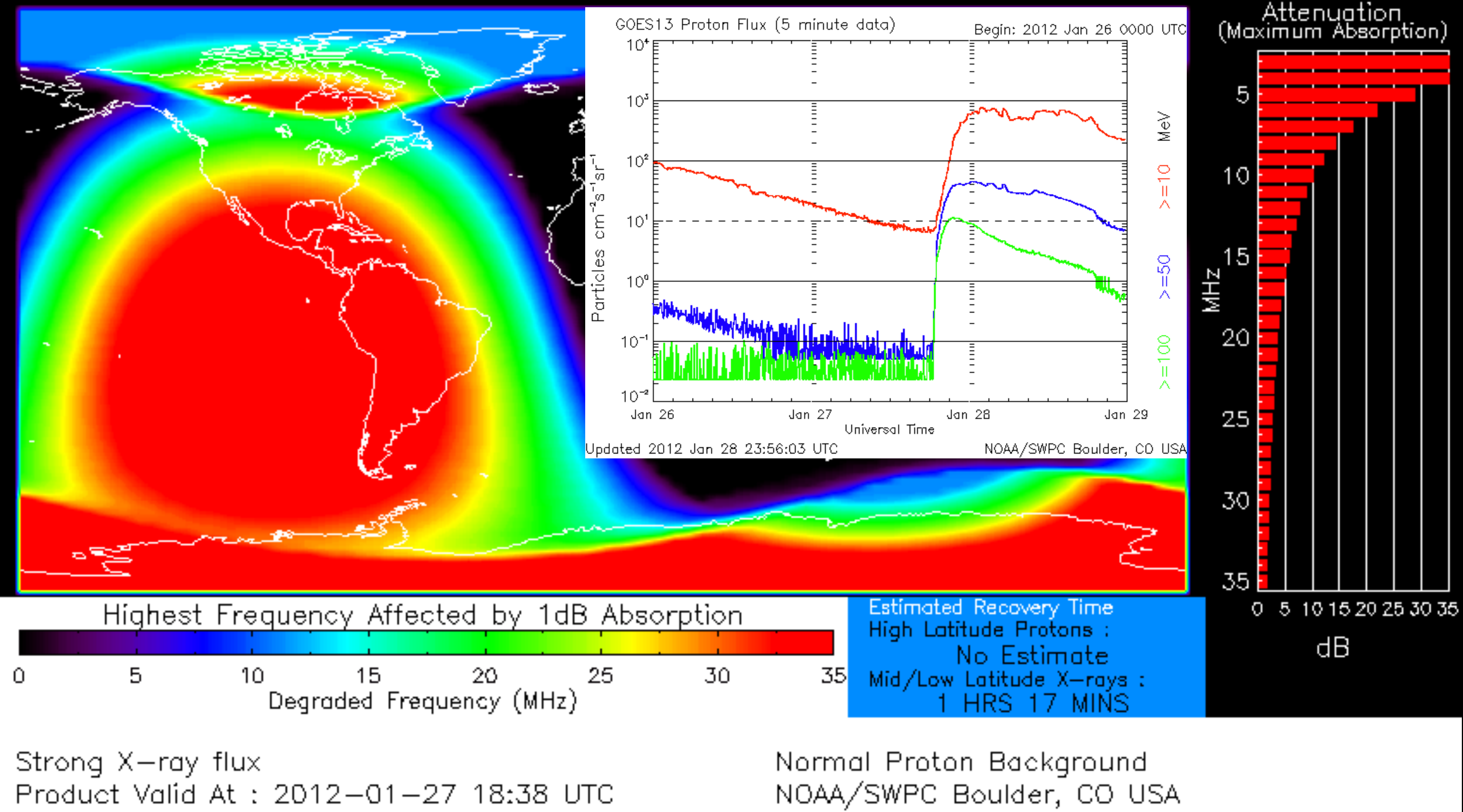


Estimated Recovery Time
High Latitude Protons :
No Estimate
Mid/Low Latitude X–rays :
1 HRS 17 MINS

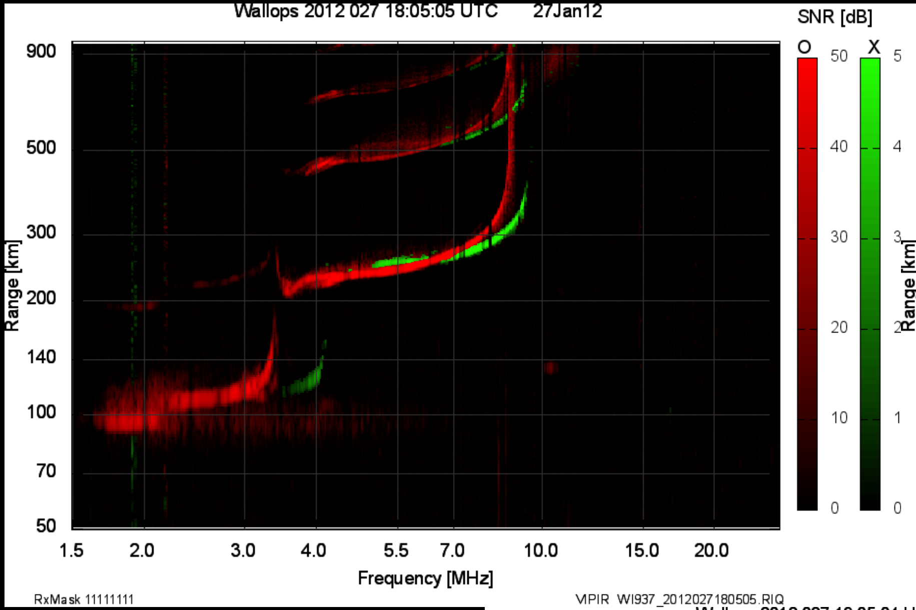
Strong X–ray flux
Product Valid At : 2012–01–27 18:38 UTC

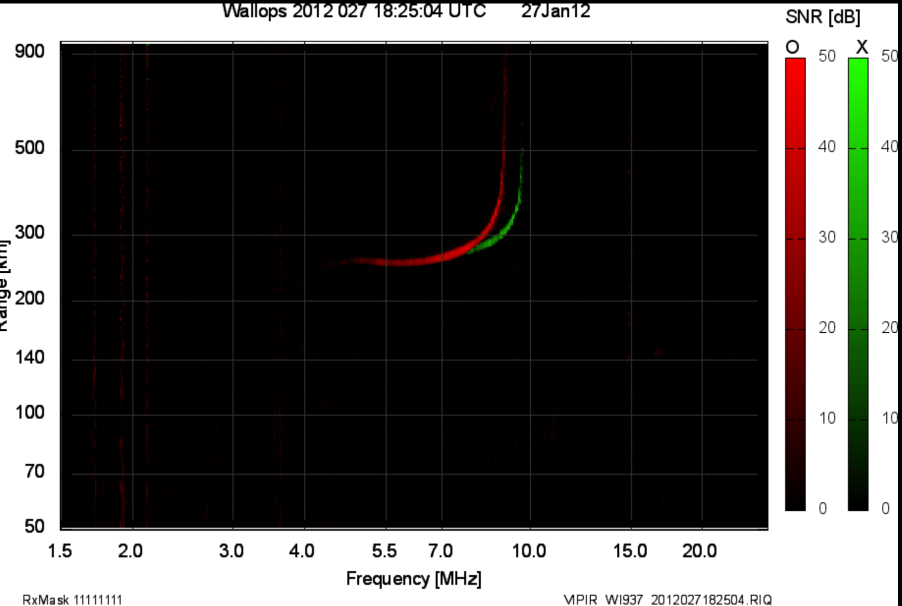
Normal Proton Background
NOAA/SWPC Boulder, CO USA

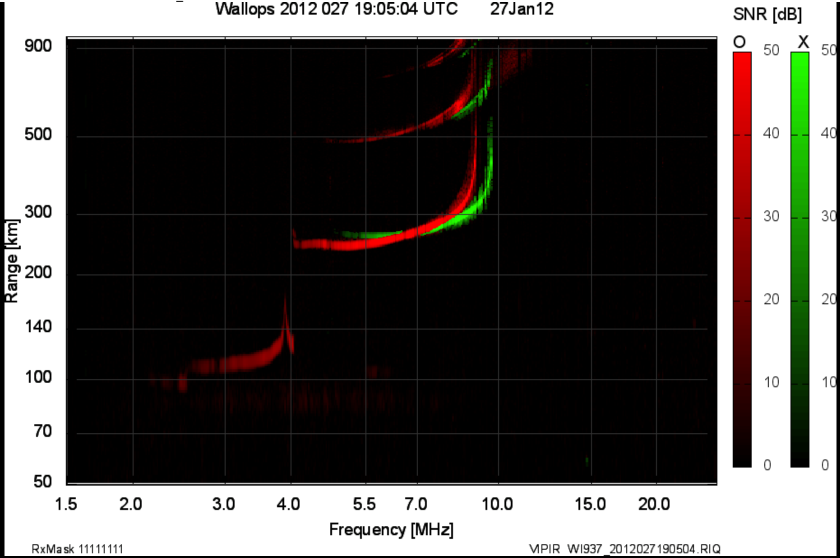
27 Jan 2012 Protons



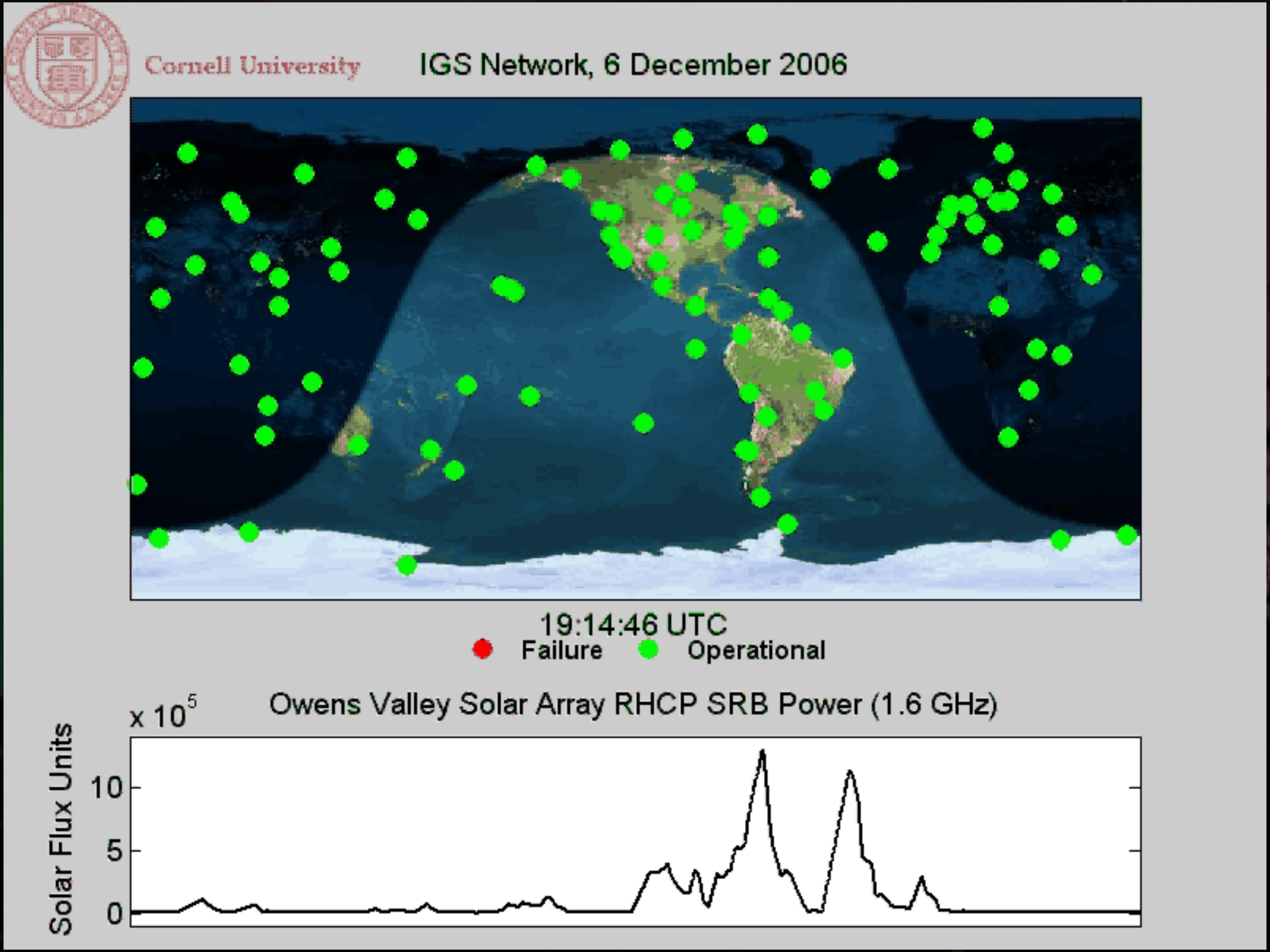
Wallops Ionogram 27 Jan 12







Solar Flare (Radio Burst) Impact on GPS – 6 Dec 2006



~10 mins

Space weather affects many forms of radio communications. The following is a sample of impacts reported to the Space Weather Prediction Center:

- Air traffic operators reported minor to severe impacts on HF communications every day between October 26 and November 05, 2003. Communications were so poor on October 30 that additional staff was necessary to handle air traffic. The New York Communication Center reported "severe operational impact."

- Nav Canada reported satellite relay of VHF air traffic messages were periodically lost in October 2003.

- The *Satellite* Operations Control Center (SOCC) at Suitland, MD reported loss of the Search and Rescue receiver signals in Nov. 2004. The signal strength was flagged red intermittently (up to 20 minutes). The cause was solar flare radio bursts.

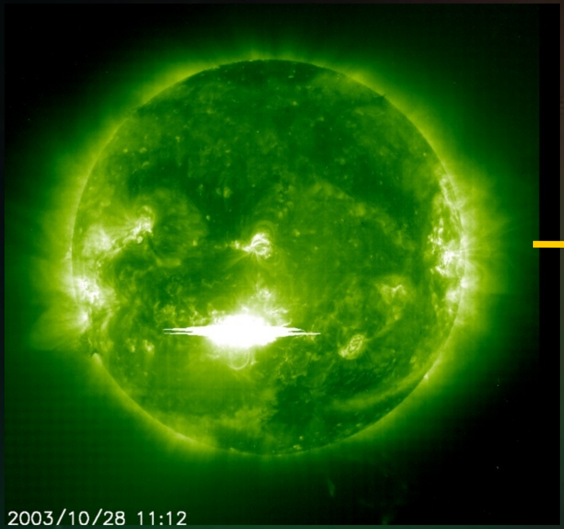
More examples…

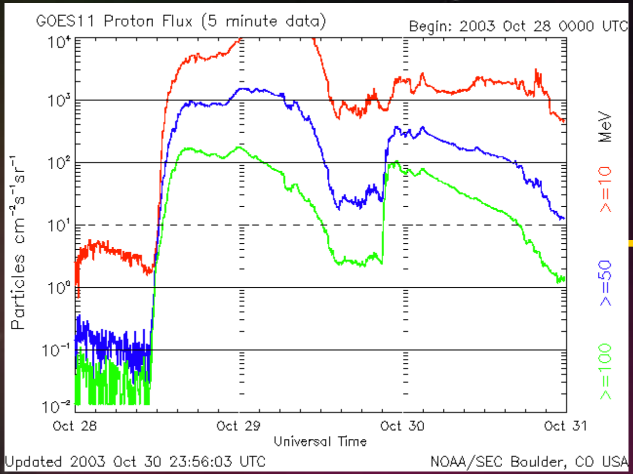
- During strong geomagnetic activity in Dec 2006, Nav Canada issued a Notice to Airman(NOTAM) restricting polar and other high latitude aviation routes for a five-day period due to communication problems.

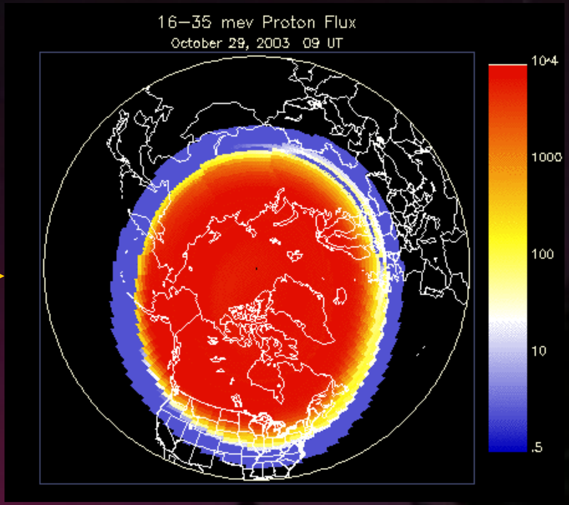
- MacRelay is responsible for communication links with aircraft and ships supporting the United States Antarctic Program. MacRelay experienced over 130 hours of High Frequency communication blackout during the October – November, 2003 solar activity.

- During several days in June 2005, space weather caused widespread interruption to radio communications. The impacts hit regions in north China hardest, but the event still reportedly extended to the far south.

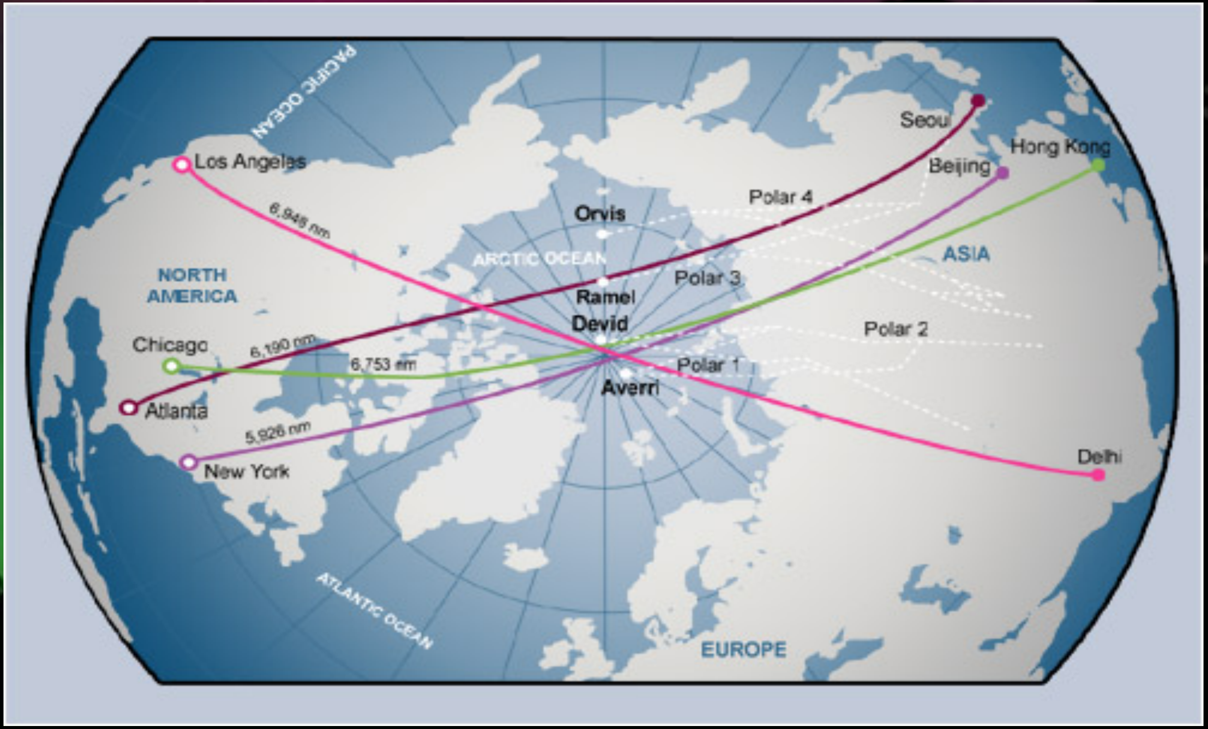
Solar Radiation Storms (S Scale)





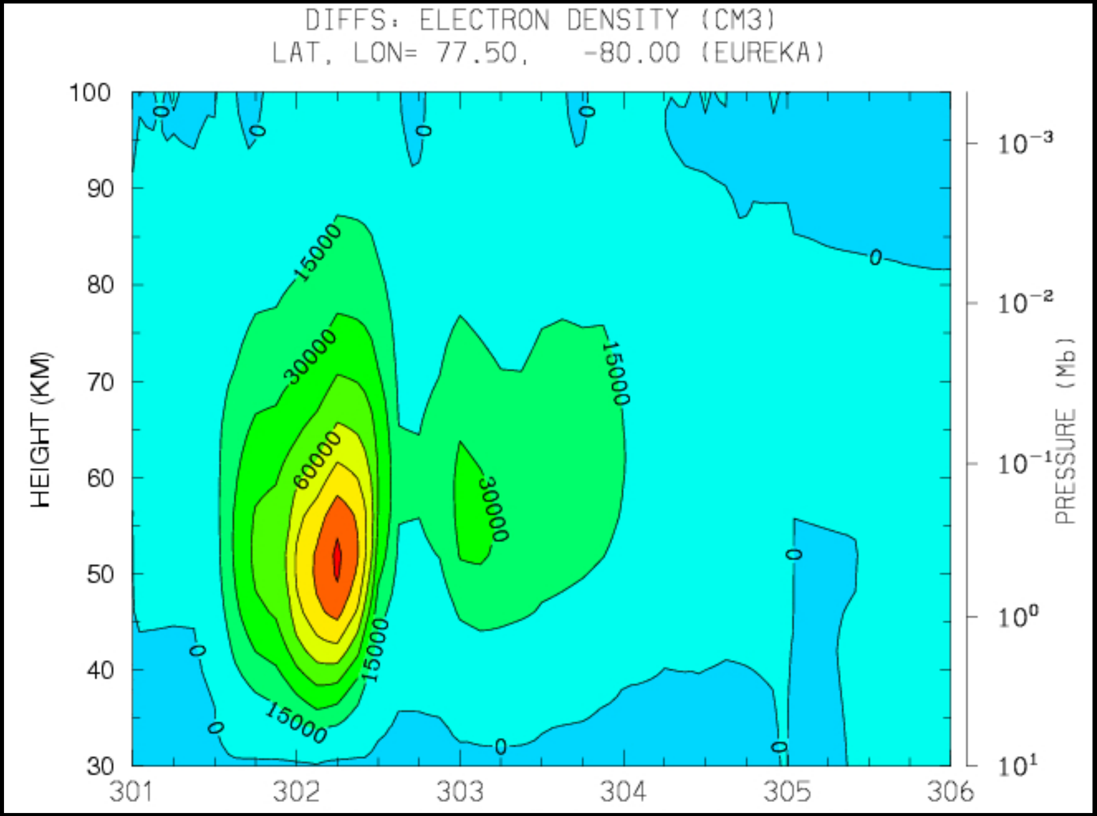


- Arrive: 30 minutes to several hours
- Lasts: hours to days



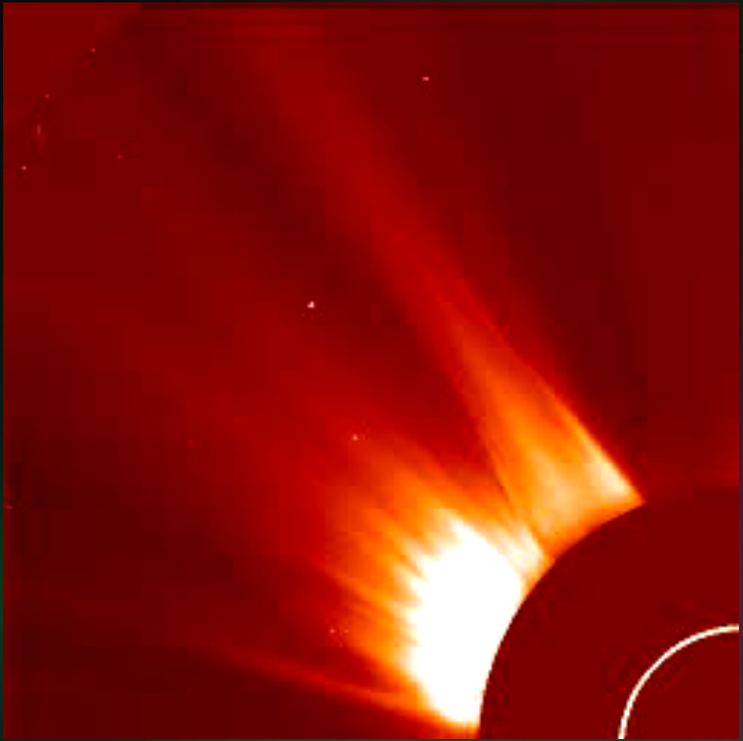
Polar Cap Absorption

- As a general rule, the more energetic the particle, the deeper into the atmosphere it penetrates



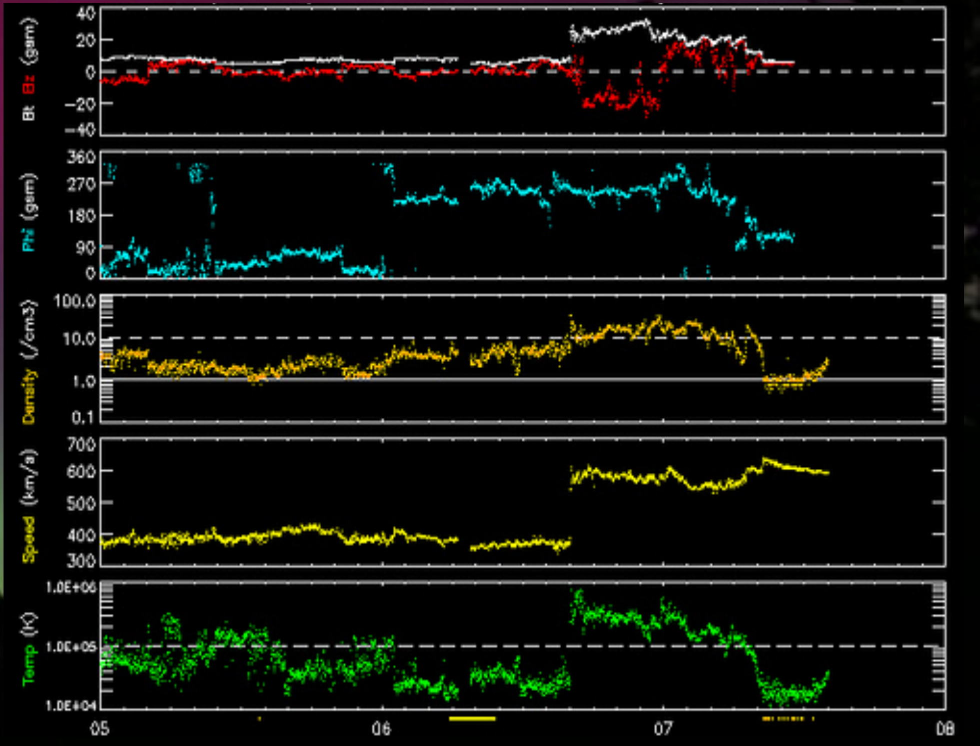
DOY

Geomagnetic Storms *(G Scale)*



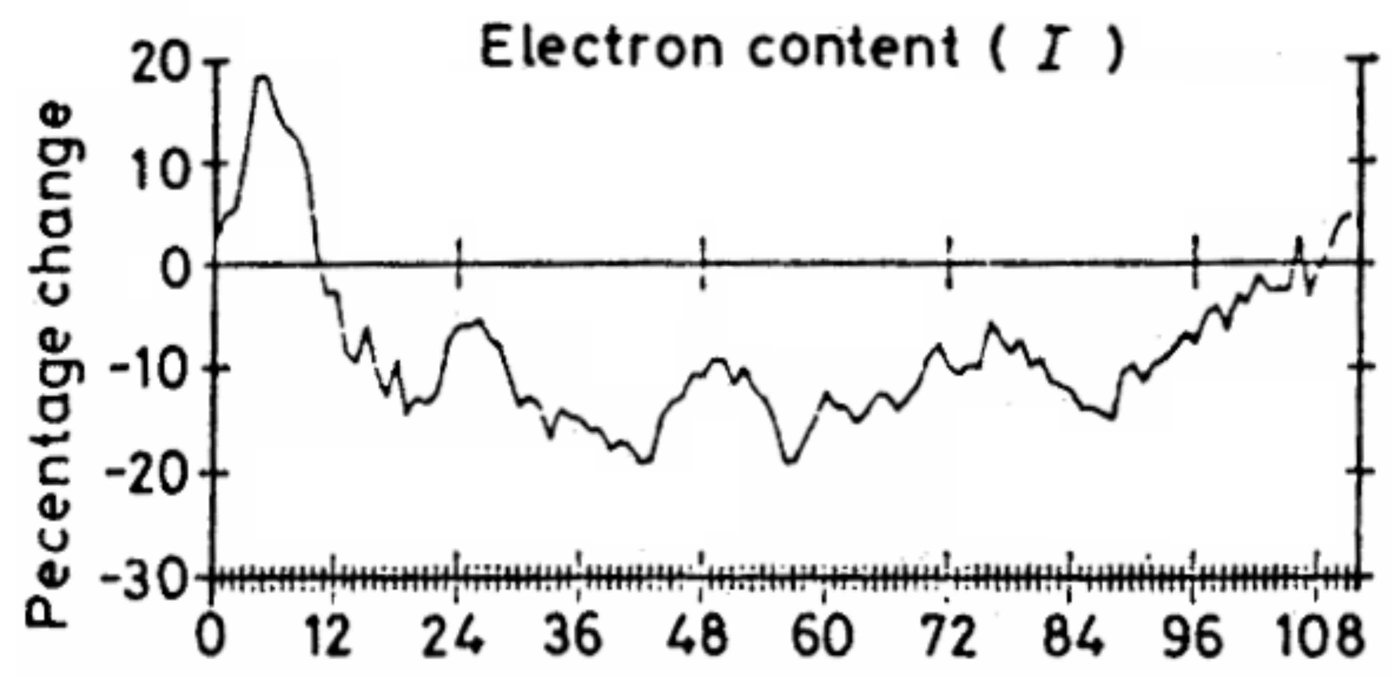
- Coronal Mass Ejections (CMEs)
  - Create Geomagnetic Storms
  - Arrive: ~18 – 96 hrs
  - Persist: ~12-48 hrs
  - Create Ionospheric Storms

- 1-2 Day **Watch** Products Based on Coronagraph Observations and Modeling
- Short-term (15 -60 min) **Warnings** Based on [illegible]



Geomagnetically Induced Ionospheric Storms

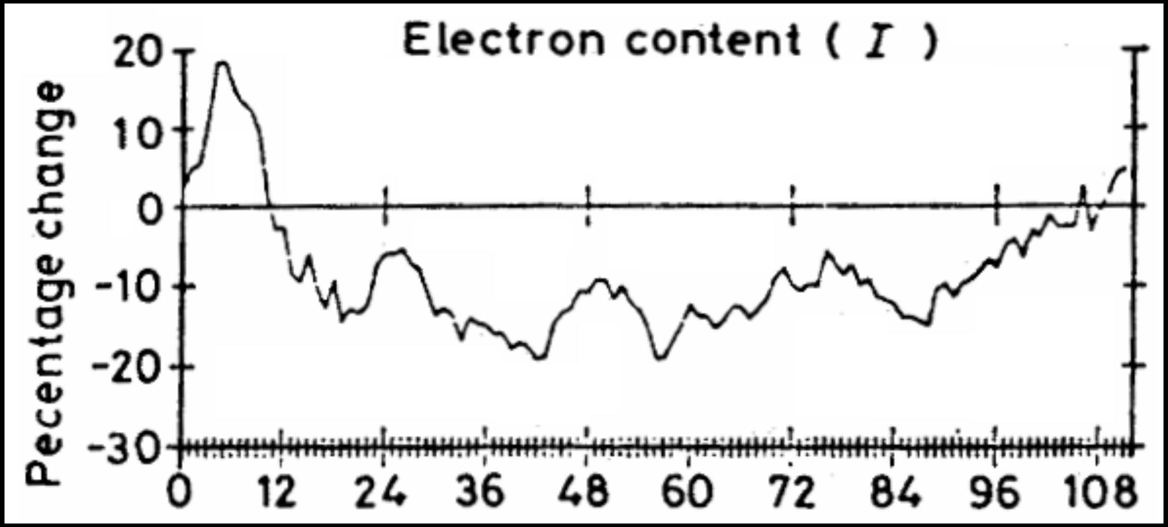
- Primarily a high and mid-latitude phenomenon
- Changes to F-region electron density driven by geomagnetic storm processes
- Temporal development often analogous to a geomagnetic storm
  - Rapid increase in electron density
  - Extended decay, followed by slow recovery

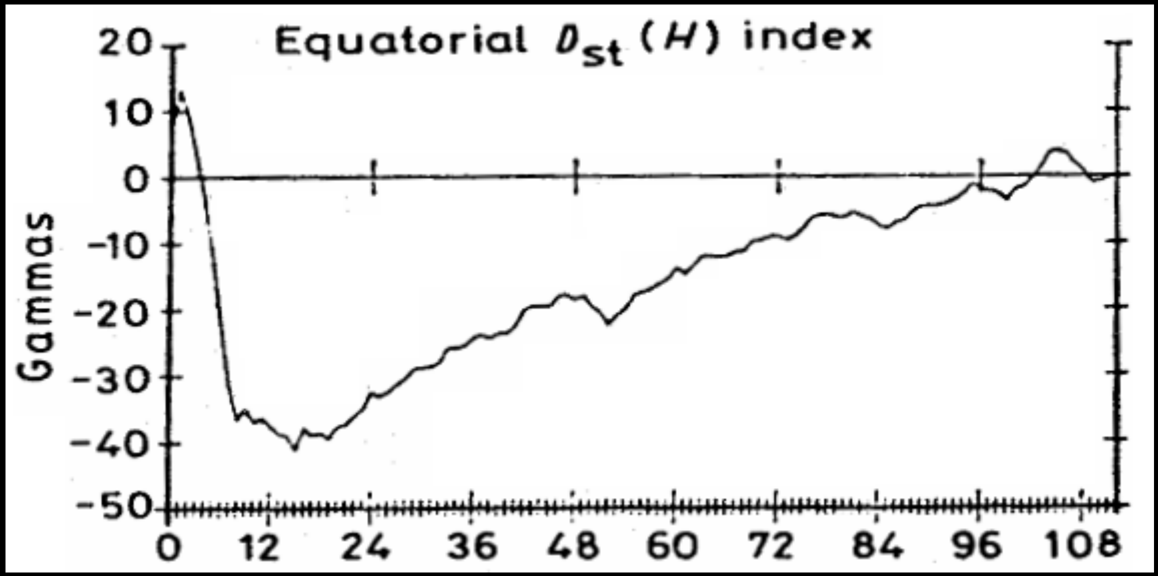


UT hour

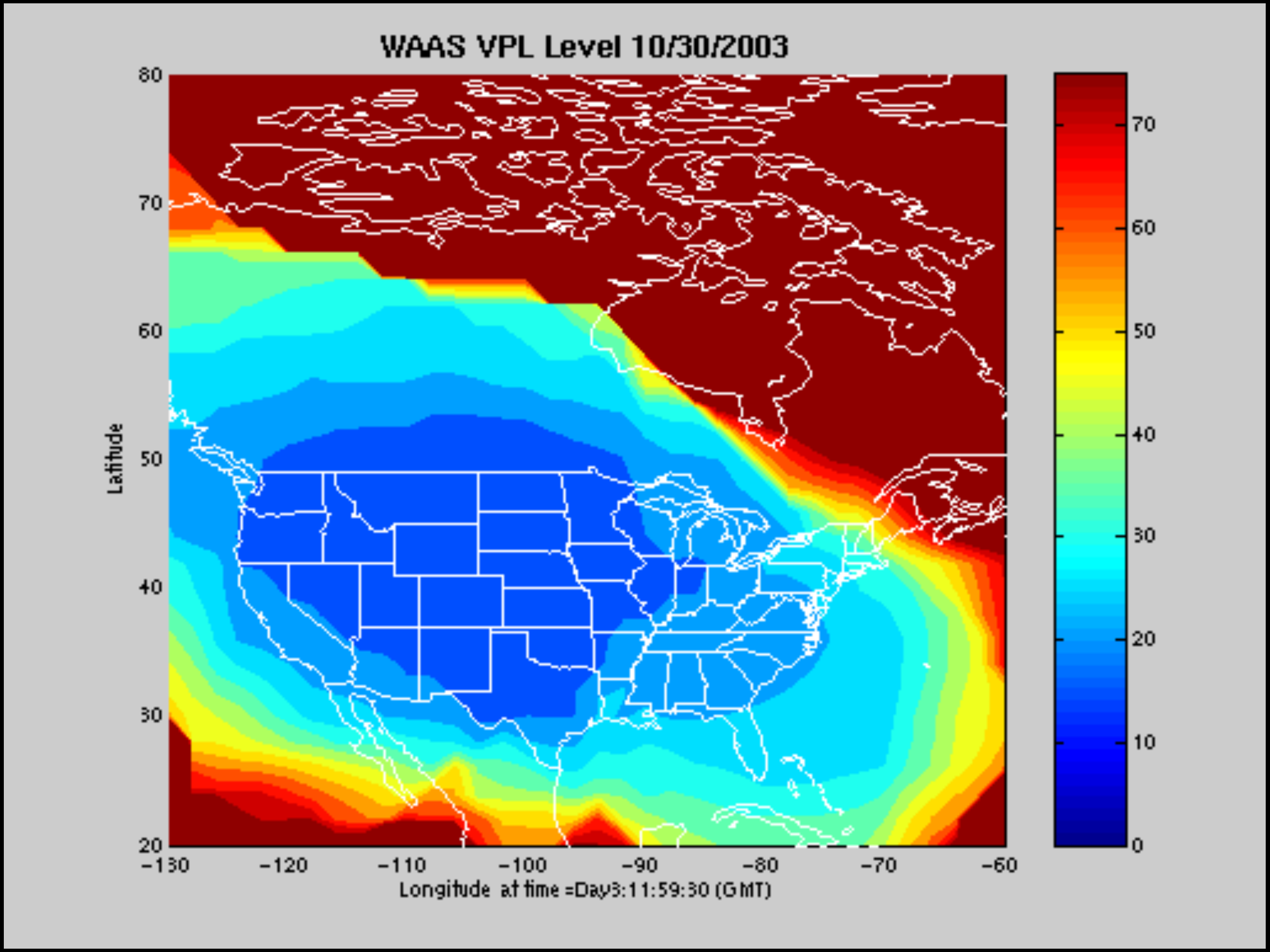
Geomagnetically Induced Ionospheric Storms

- Although progression often similar to geomagnetic storm, many counter examples as well
- Complex physical processes that are not well understood
- Still many different theories and no satisfying complete answer



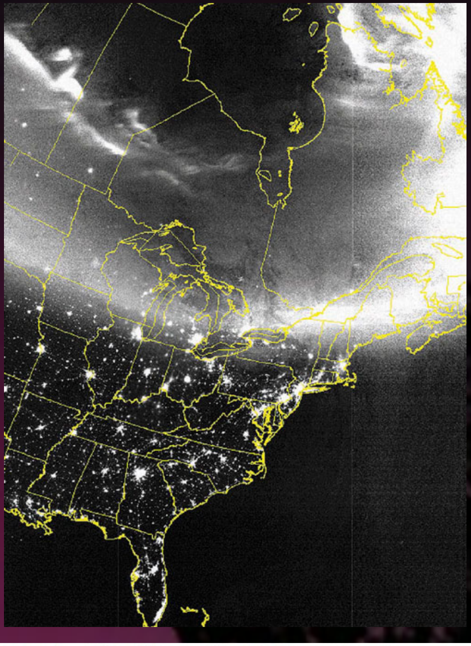


Mendillo, Planet. Space Sci., 1973


WAAS VPL Level 10/30/2003
Latitude
80
70
60
50
40
30
20
-130
-120
-110
-100
-90
-80
-70
-60
Longitude at time =Day3:11:59:30 (GMT)
70
60
50
40
30
20
10
0

Impacts on Electric Power Grid

- CME impacts Earth’s magnetic field
- Fluctuations generate electric fields on Earth. These geomagnetically induced currents (GIC) can flow into power lines and transformers
- Leads to transformer saturation and over-heating, voltage drops, transformer damage, or protective device trips



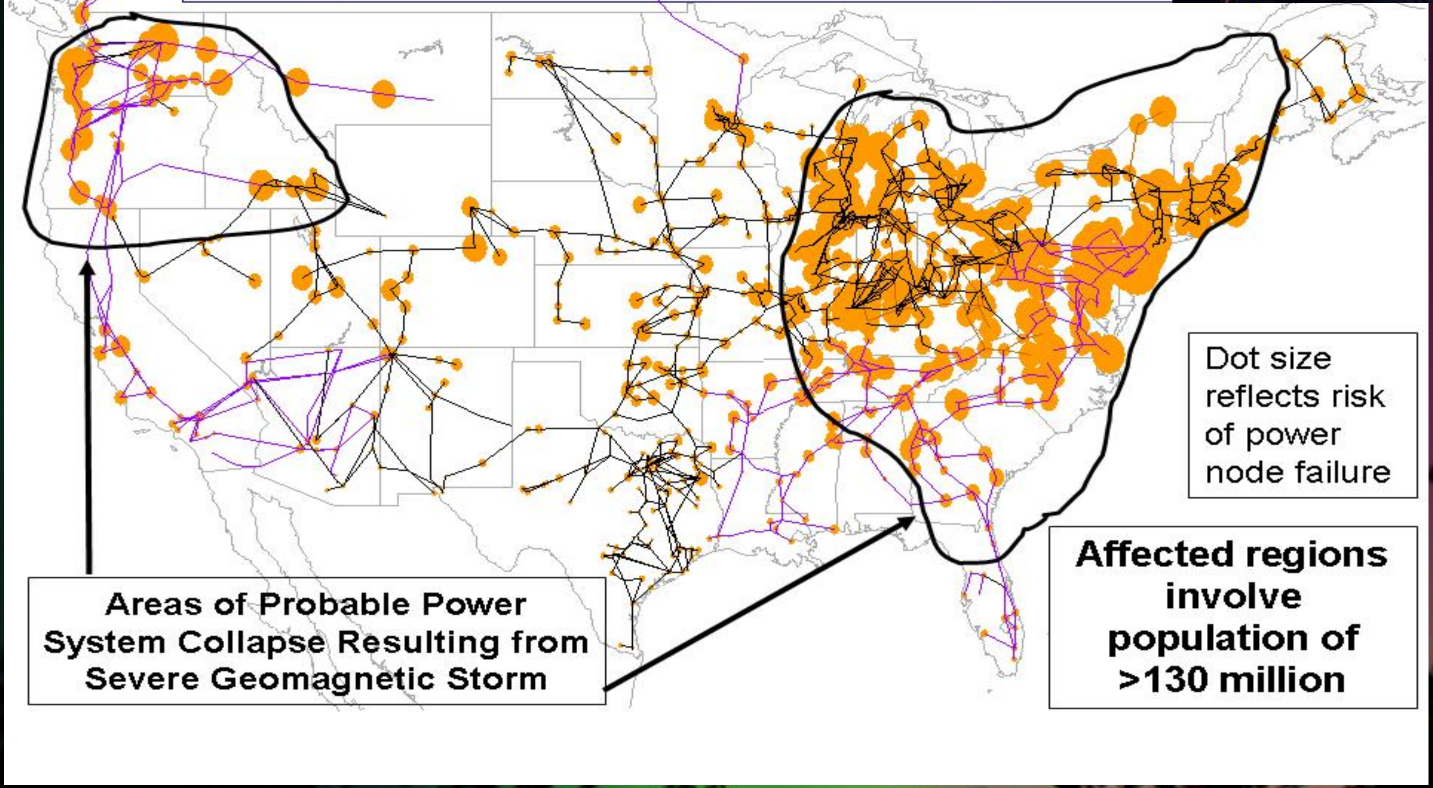
Transformer winding failure

Transformer exit-lead overheating

Worst Case…

From National Research Council (NRC) report, "Severe Space Weather Events" (20

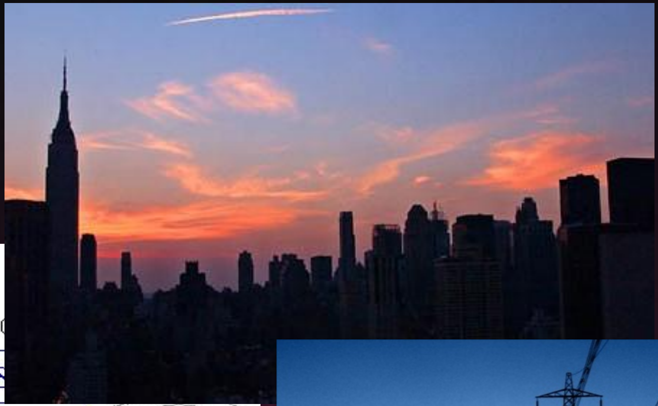
Power System Disturbance and Outage Scenario of Unprecedented S

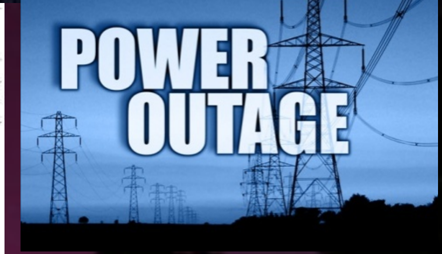


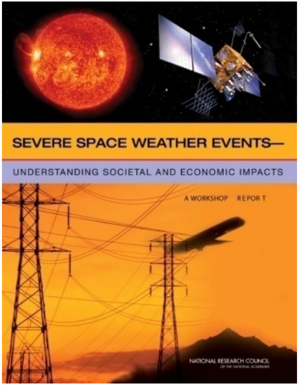
Dot size reflects risk of power node failure

Affected regions involve population of >130 million

Areas of Probable Power System Collapse Resulting from Severe Geomagnetic Storm






SEVERE SPACE WEATHER EVENTS—
UNDERSTANDING SOCIETAL AND ECONOMIC IMPACTS
A WORKSHOP REPORT
NATIONAL RESEARCH COUNCIL

Situational Awareness

NOAA Space Weather Prediction Center

Boulder, Colorado

Space Weather Products and Services

- **Watches**; The conditions are favorable for occurrence
- **Warnings**; disturbances that are imminent, expected in the near future with high probability
- **Alerts**; observed conditions meeting or exceeding thresholds

Email Product Subscription Service

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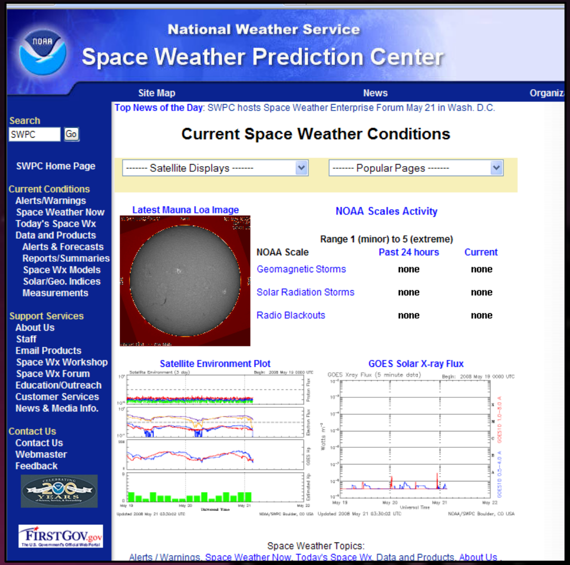

National Weather Service

Space Weather Prediction Center

Site Map News Organiz

Top News of the Day: SWPC hosts Space Weather Enterprise Forum May 21 in Wash. D.C.

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Current Space Weather Conditions

------- Satellite Displays ------- ------- Popular Pages -------

Latest Mauna Loa Image

NOAA Scales Activity

Range 1 (minor) to 5 (extreme)

NOAA Scale	Past 24 hours	Current
Geomagnetic Storms	none	none
Solar Radiation Storms	none	none
Radio Blackouts	none	none

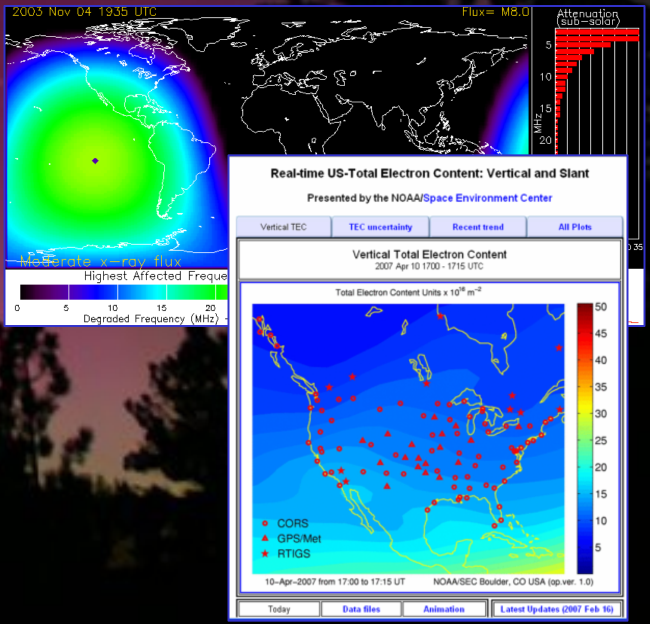
Satellite Environment Plot

GOES Solar X-ray Flux

Space Weather Topics:

Alerts / Warnings, Space Weather Now, Today's Space Wx, Data and Products, About Us

Satellite Environment (3 day)
Begin: 2008 May 19 0000 UTC
Proton Flux
Electron Flux
GOES Hp
Estimated Kp
May 19
May 20
May 21
May 22
Universal Time
Updated 2008 May 21 03:30:02 UTC
NOAA/SWPC Boulder, CO USA
GOES Xray Flux (5 minute data)
Begin: 2008 May 19 0000 UTC
Watts m⁻²
GOES10 1.0–8.0 A
GOES10 0.5–4.0 A
X
M
C
B
A
Universal Time
Updated 2008 May 21 03:30:02 UTC
NOAA/SWPC Boulder, CO USA
CELEBRATING 200 YEARS
FIRSTGOV.gov
The U.S. Government's Official Web Portal



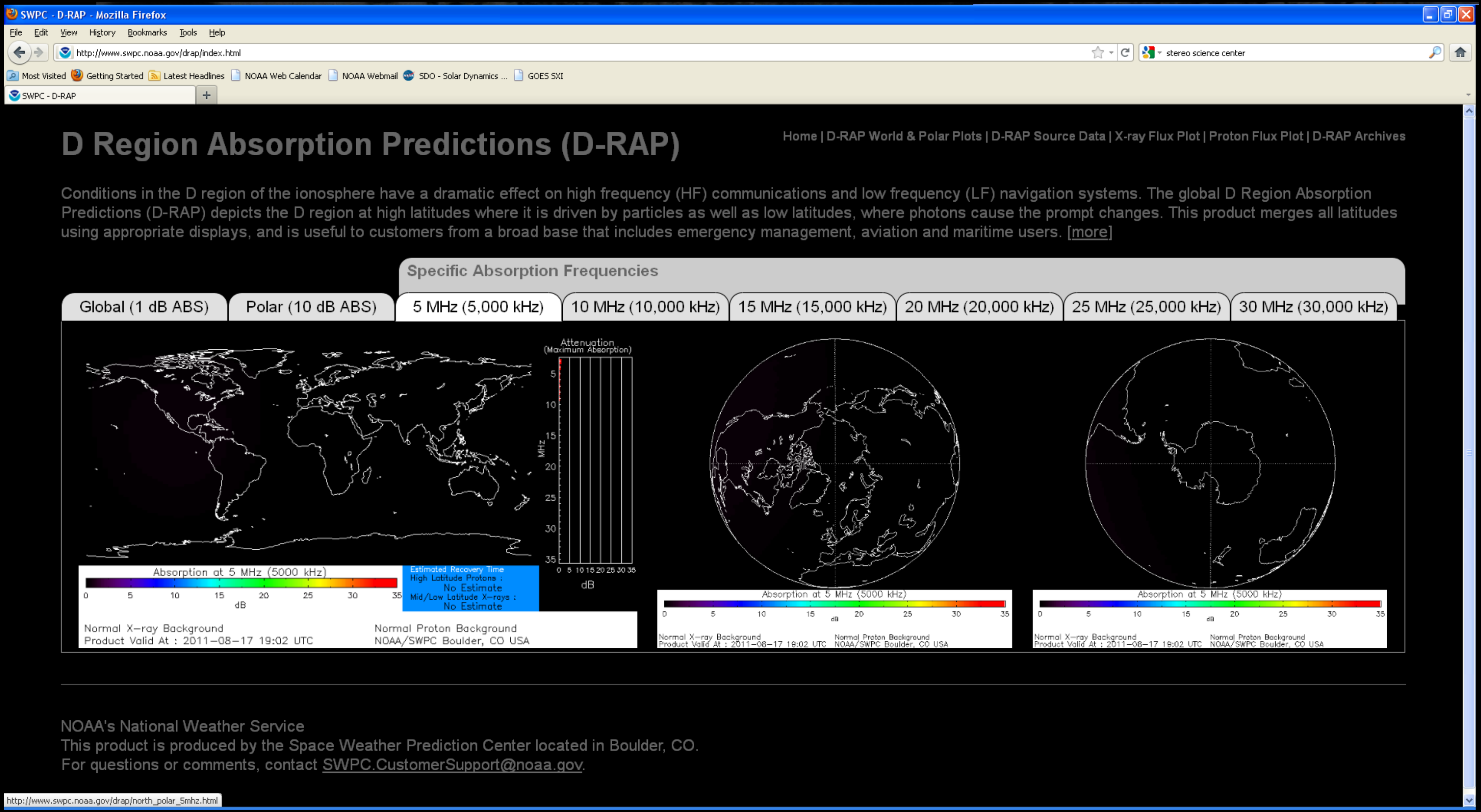
Real-time US-Total Electron Content: Vertical and Slant

Presented by the NOAA/Space Environment Center

Vertical Total Electron Content

2007 Apr 10 1700 - 1715 UTC

D-RAP Page at www.spaceweather.gov



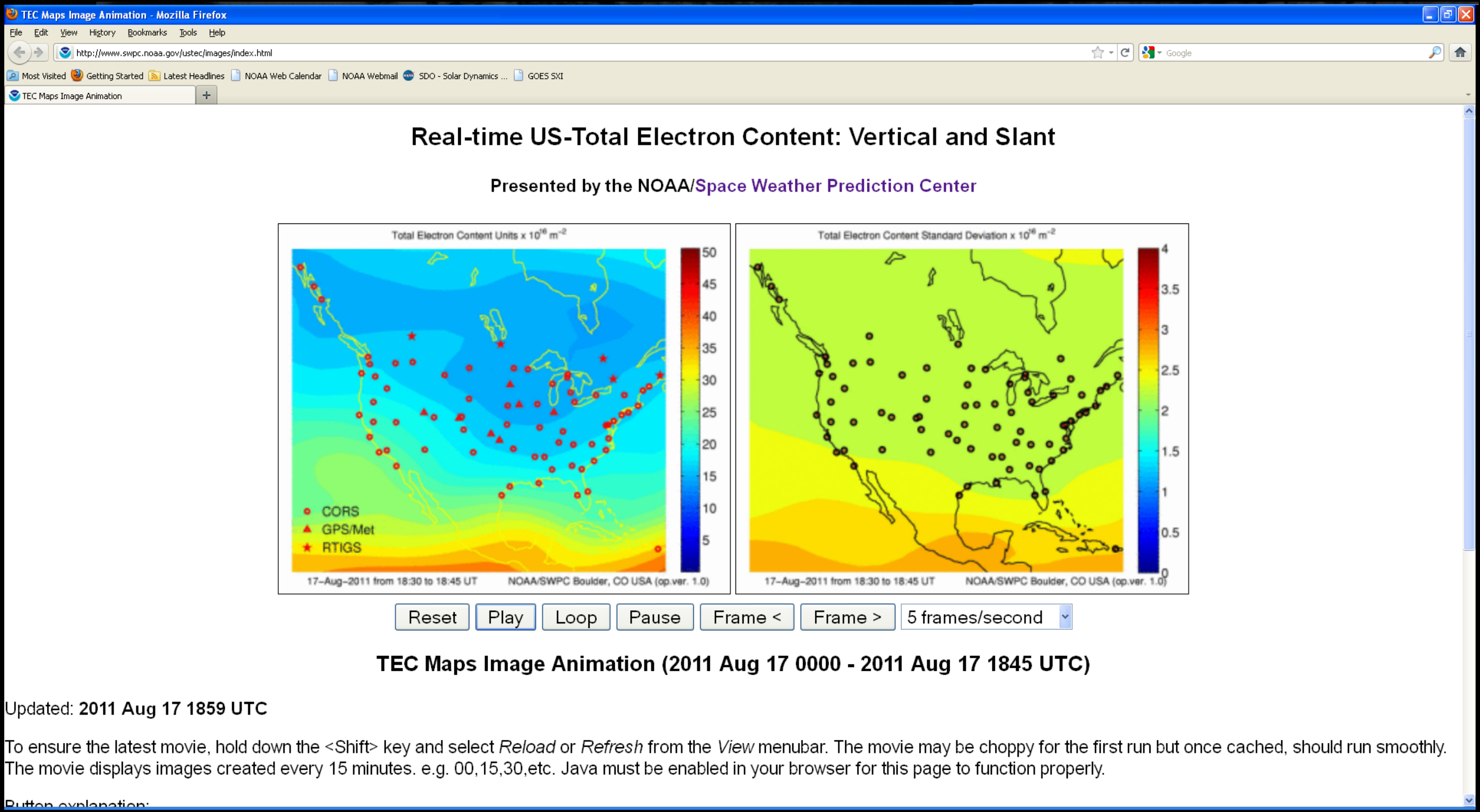
D Region Absorption Predictions (D-RAP)

Home | D-RAP World & Polar Plots | D-RAP Source Data | X-ray Flux Plot | Proton Flux Plot | D-RAP Archives

Conditions in the D region of the ionosphere have a dramatic effect on high frequency (HF) communications and low frequency (LF) navigation systems. The global D Region Absorption Predictions (D-RAP) depicts the D region at high latitudes where it is driven by particles as well as low latitudes, where photons cause the prompt changes. This product merges all latitudes using appropriate displays, and is useful to customers from a broad base that includes emergency management, aviation and maritime users. [more]

NOAA's National Weather Service
This product is produced by the Space Weather Prediction Center located in Boulder, CO.
For questions or comments, contact SWPC.CustomerSupport@noaa.gov.

US-TEC Maps at www.spaceweather.gov



TEC Maps Image Animation - Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://www.swpc.noaa.gov/ustec/images/index.html
Google
Most Visited
Getting Started
Latest Headlines
NOAA Web Calendar
NOAA Webmail
SDO - Solar Dynamics ...
GOES SXI
TEC Maps Image Animation
Total Electron Content Units x 10^{16} m^{-2}
50
45
40
35
30
25
20
15
10
5
CORS
GPS/Met
RTIGS
17-Aug-2011 from 18:30 to 18:45 UT
NOAA/SWPC Boulder, CO USA (op.ver. 1.0)
Total Electron Content Standard Deviation x 10^{16} m^{-2}
4
3.5
3
2.5
2
1.5
1
0.5
0
17-Aug-2011 from 18:30 to 18:45 UT
NOAA/SWPC Boulder, CO USA (op.ver. 1.0)
Reset
Play
Loop
Pause
Frame <
Frame >
5 frames/second

Real-time US-Total Electron Content: Vertical and Slant

Presented by the NOAA/Space Weather Prediction Center

TEC Maps Image Animation (2011 Aug 17 0000 - 2011 Aug 17 1845 UTC)

Updated: **2011 Aug 17 1859 UTC**

To ensure the latest movie, hold down the <Shift> key and select *Reload* or *Refresh* from the *View* menubar. The movie may be choppy for the first run but once cached, should run smoothly. The movie displays images created every 15 minutes. e.g. 00,15,30,etc. Java must be enabled in your browser for this page to function properly.

Button explanation:

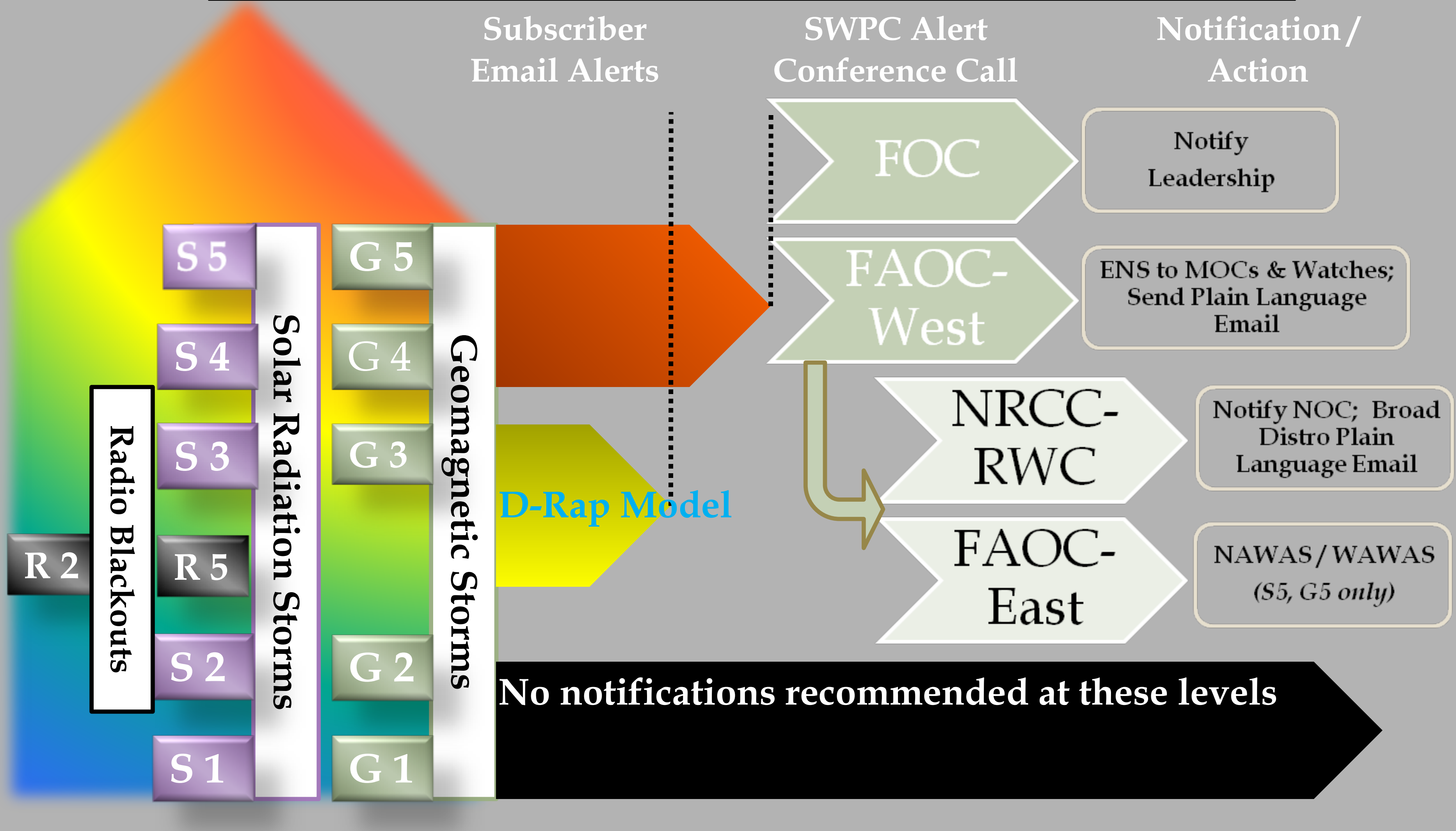
Emcomm Perspective

Interest and appropriate product subscriptions will vary based on the technologies or systems in use:

- Solar Flare - Radio Blackout
  - HF/Ham Radio Community (R-Scale Alert – R2, D-RAP Product)
  - Occasional, Short-Lived Disruption to GPS
- Solar Radiation Storms
  - Polar Aviation (S-Scale Alerts & Warnings, D-RAP Product)
  - Satellite Operations
- Geomagnetic Storms
  - Power Grid Operations (G-Scale AWW, G3 or Greater Primarily)
  - GPS Availability and Accuracy (G-Scale AWW, US-TEC Product)

Take What You Read and Hear With a Grain of Salt – When It's Big, We'll Be the First to Say So

Space Weather Event Alert & Notification Process



Summary

- Solar Cycle 24 is underway
- Ionosphere
- Propagation
- Space Weather
- Space Situational Awareness

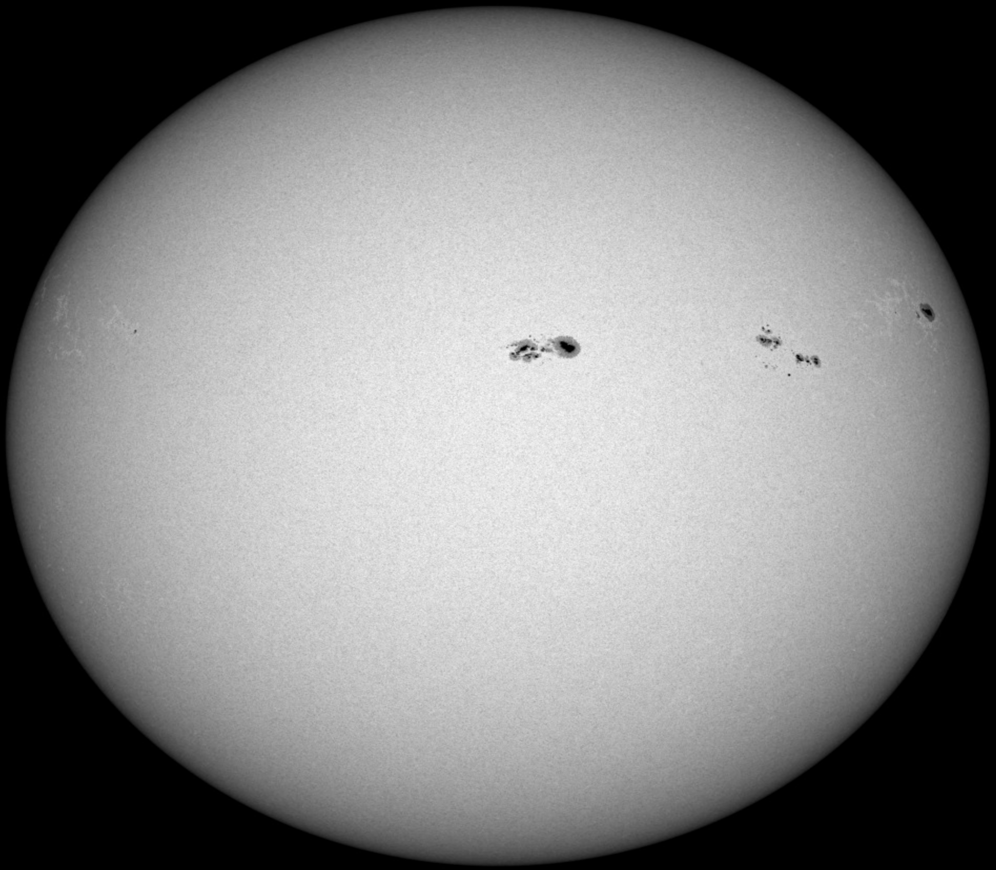
Questions?

Scenario

K7 Event of 05 August 2011

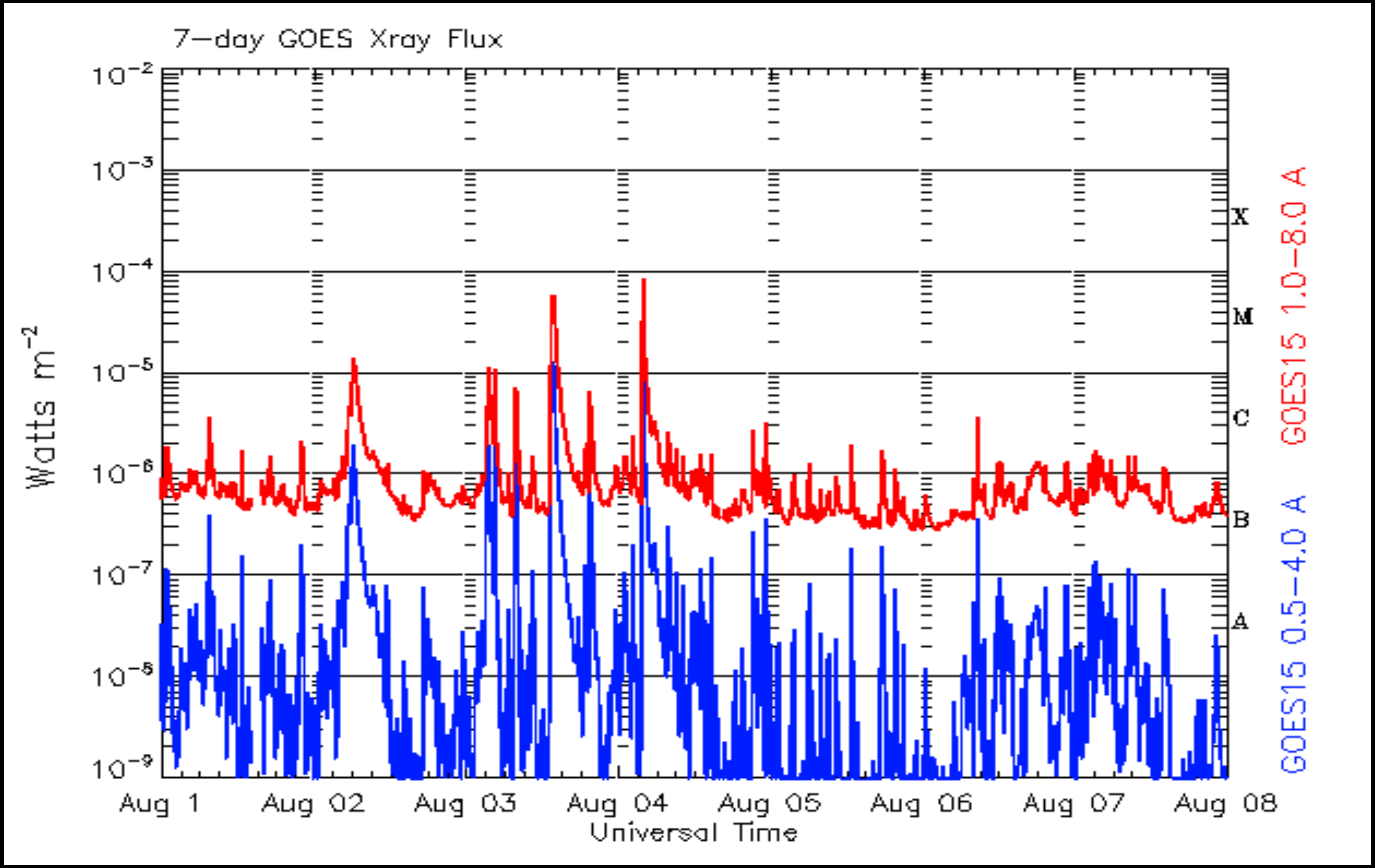
HMI

HMIB

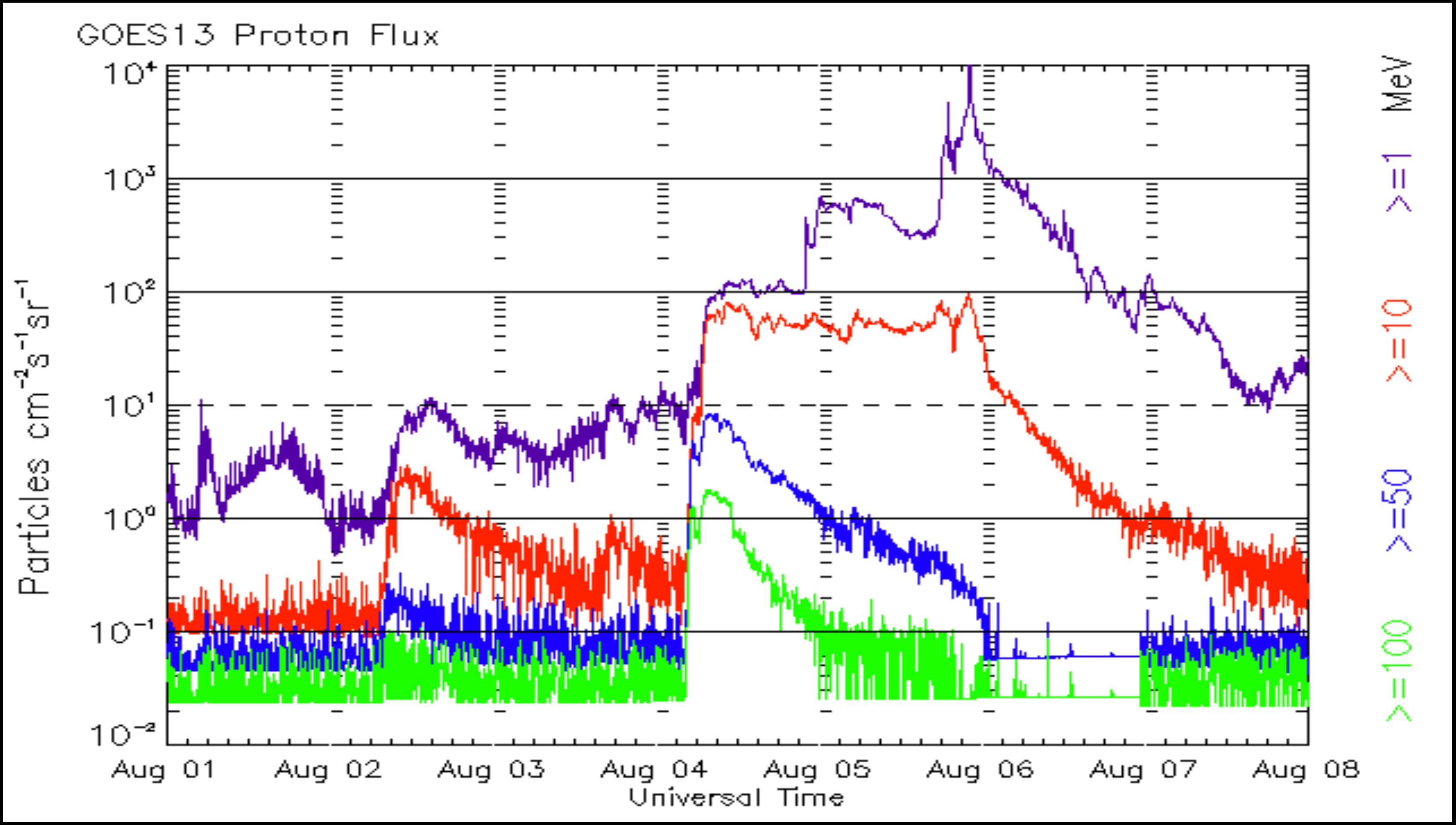


SDO/HMI Quick-Look Continuum: 2011.08.04_01:58:30_TAI

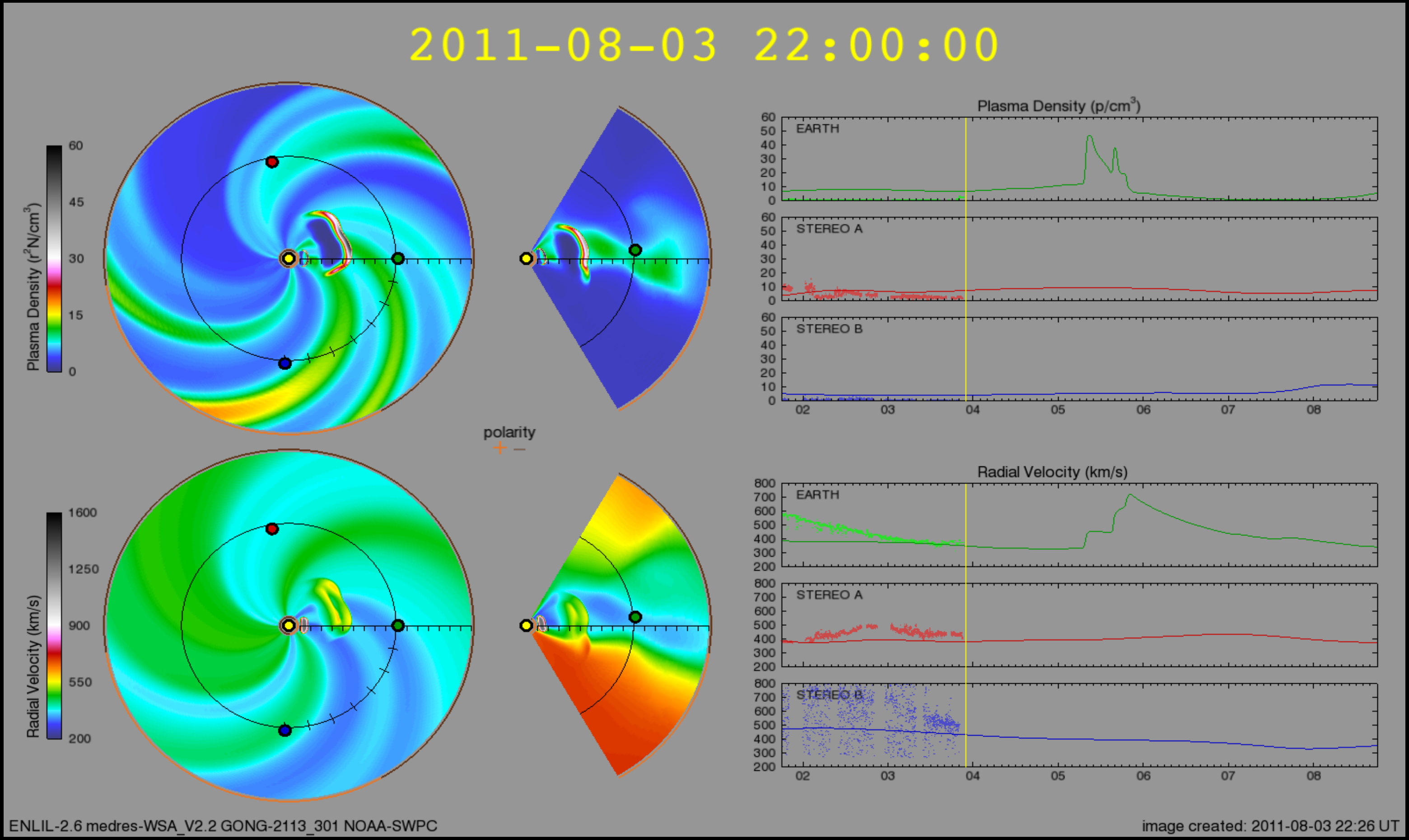
2-5 August 2011 Flare Activity



01-08 August 2011 Proton Activity



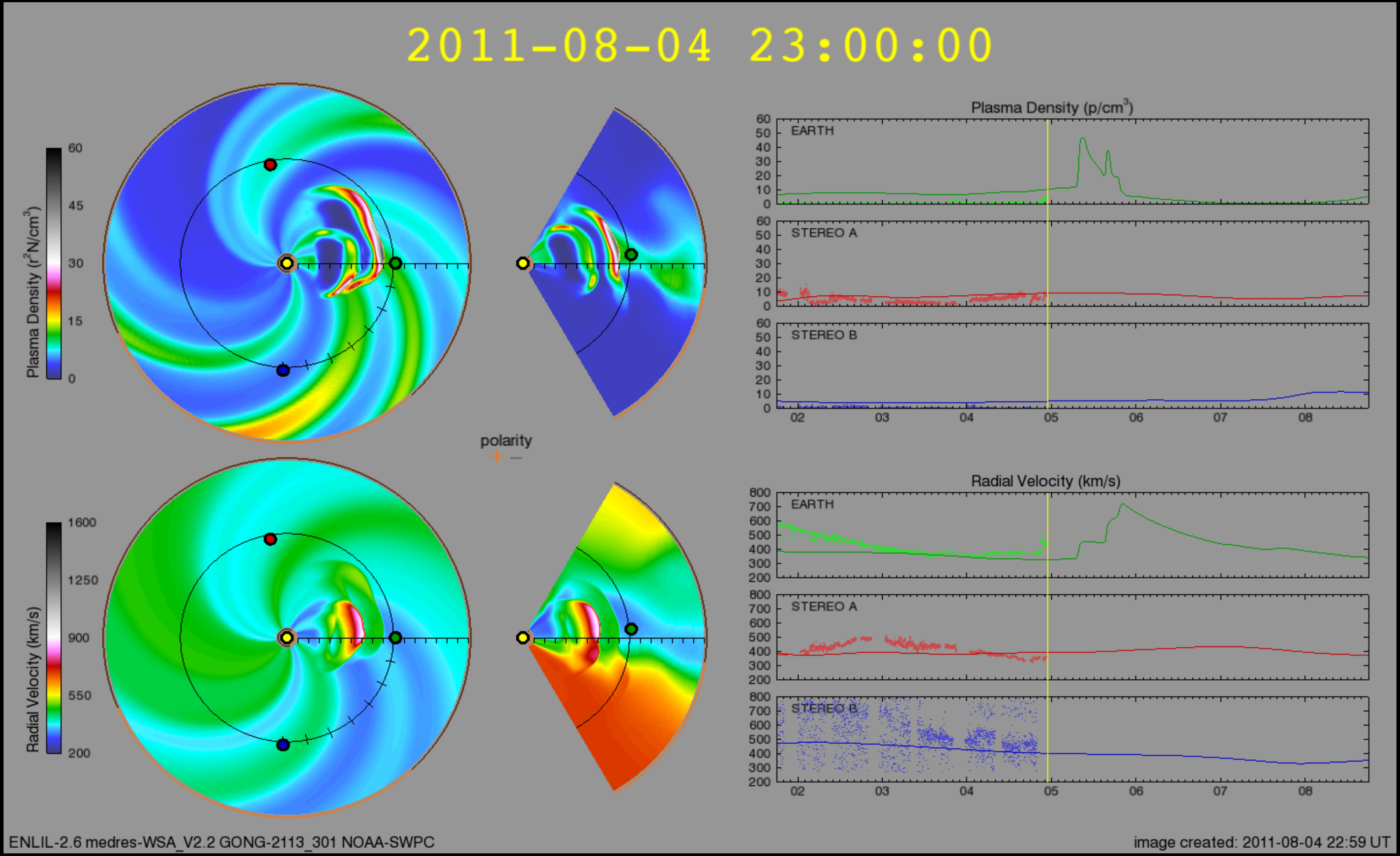
ENLIL Model Prediction
03 August 2011



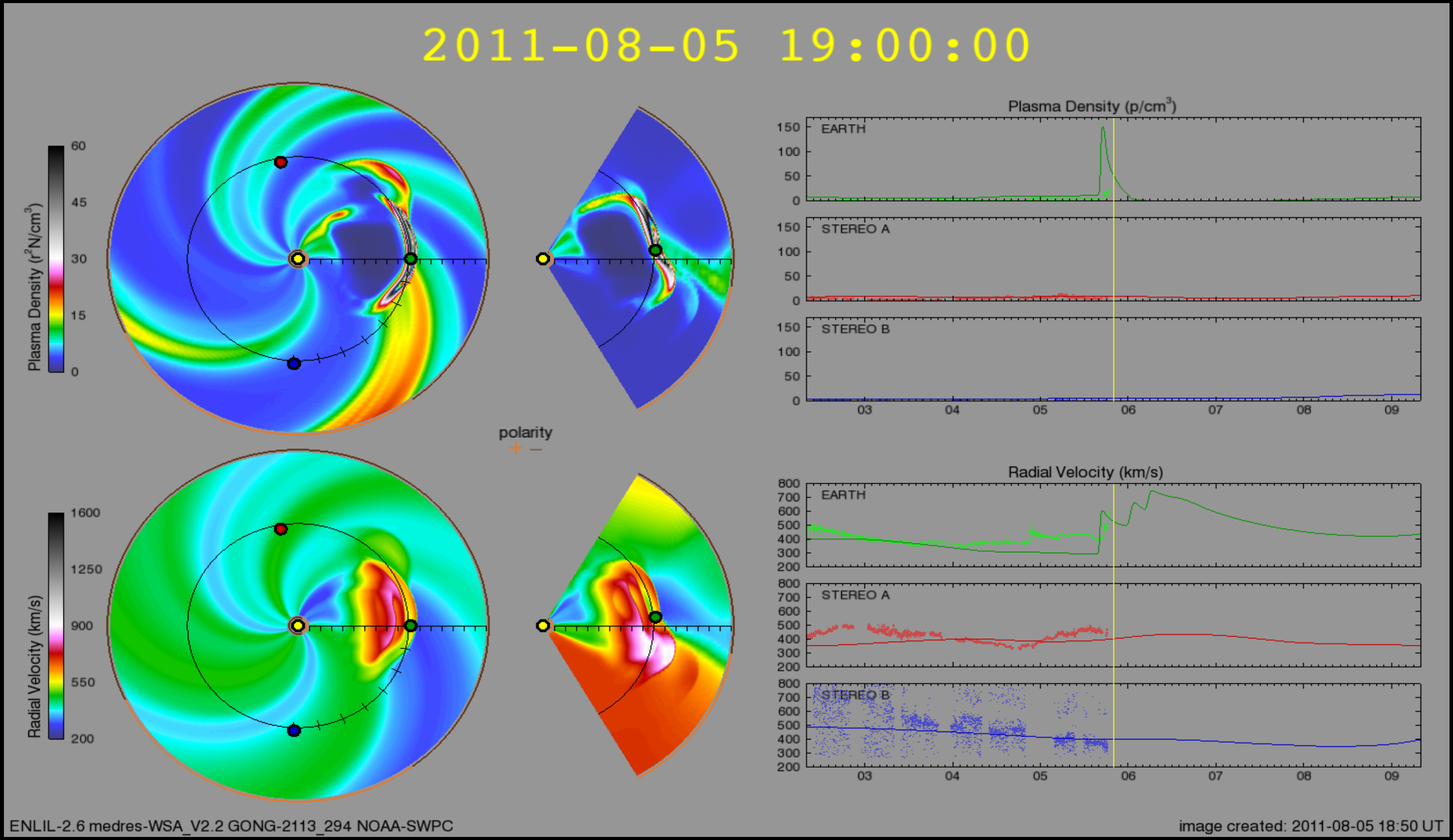
ENLIL-2.6 medres-WSA_V2.2 GONG-2113_301 NOAA-SWPC

image created: 2011-08-03 22:26 UT

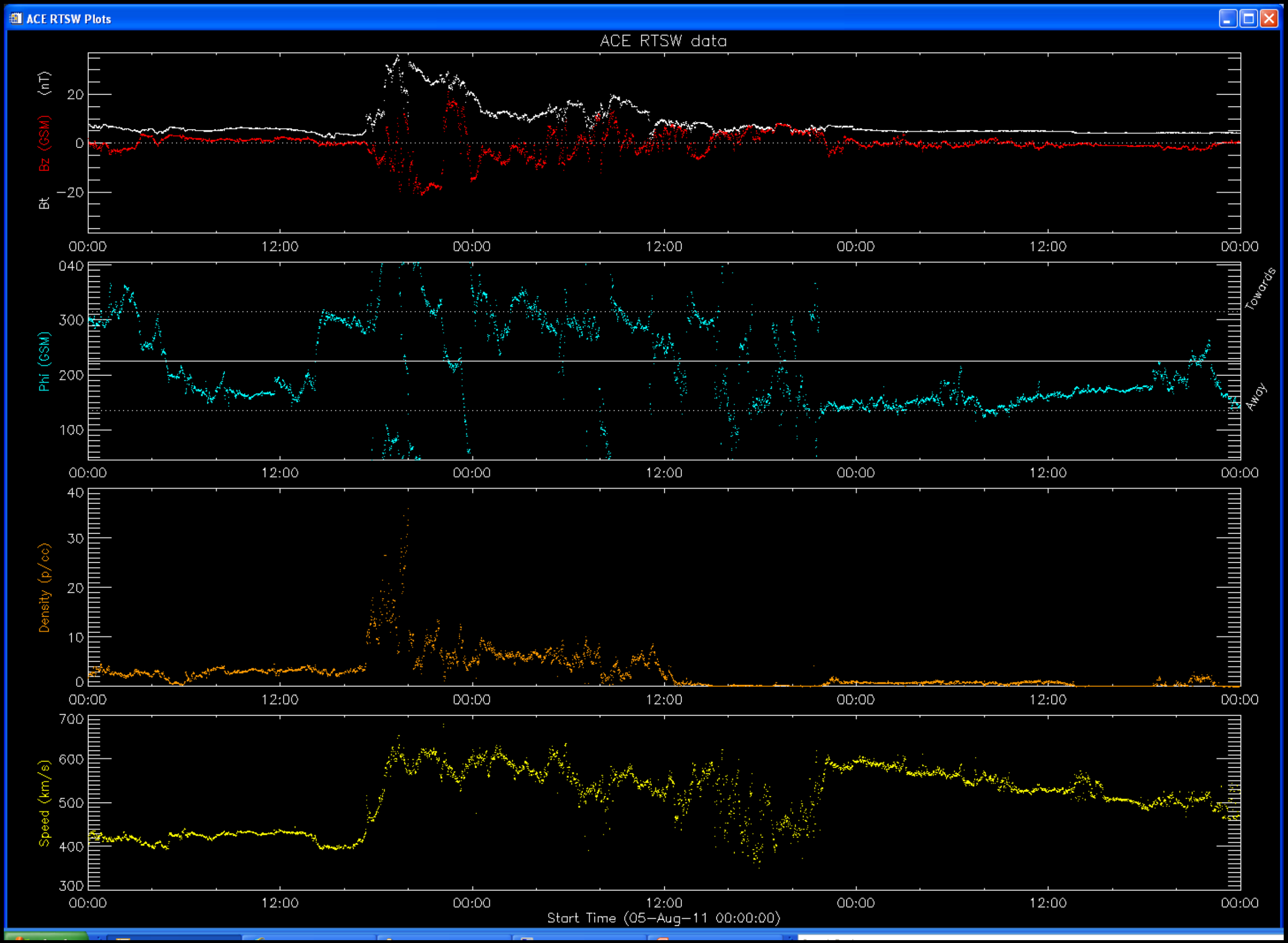
ENLIL Prediction
04 August 2011



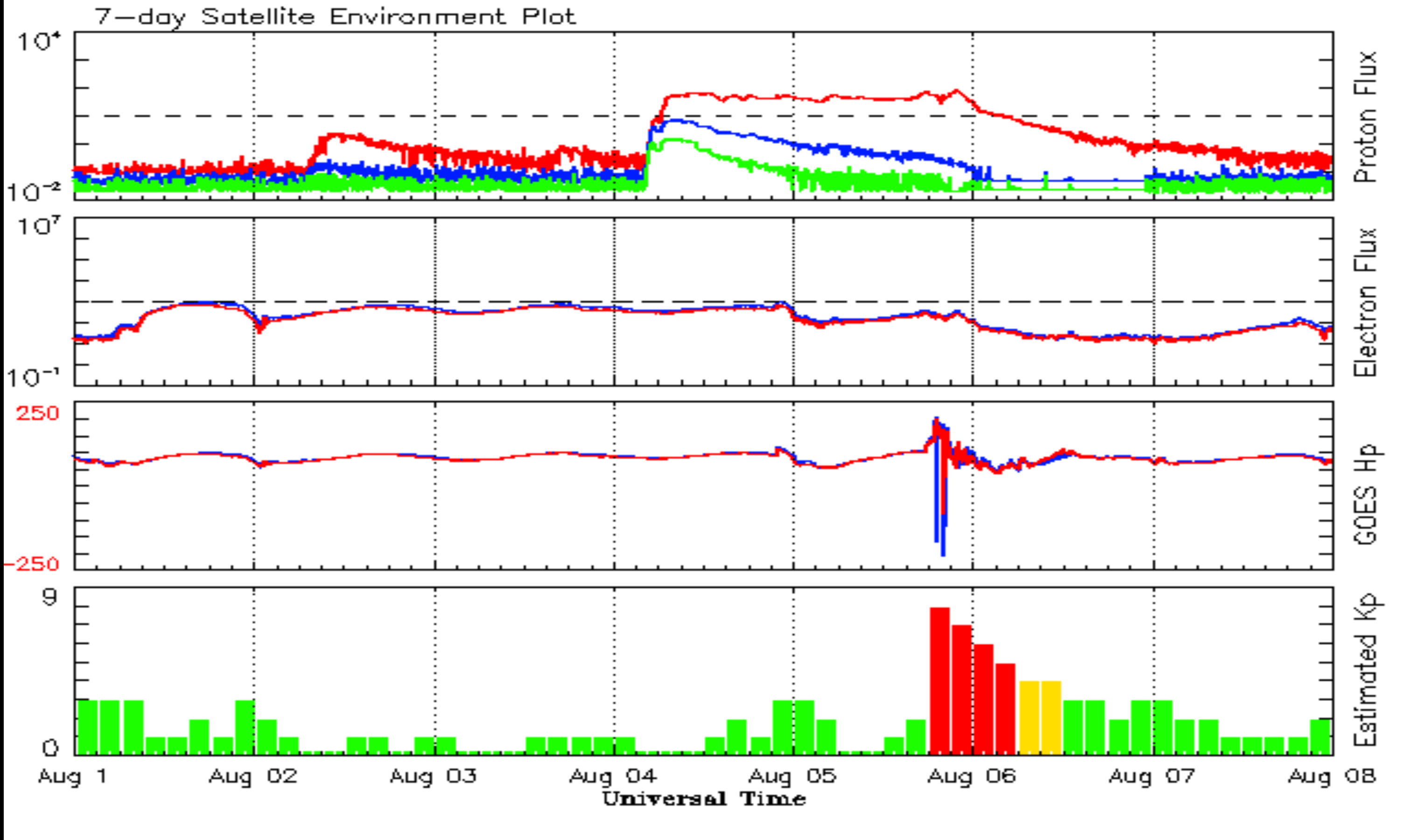
ENLIL Prediction
05 August 2011



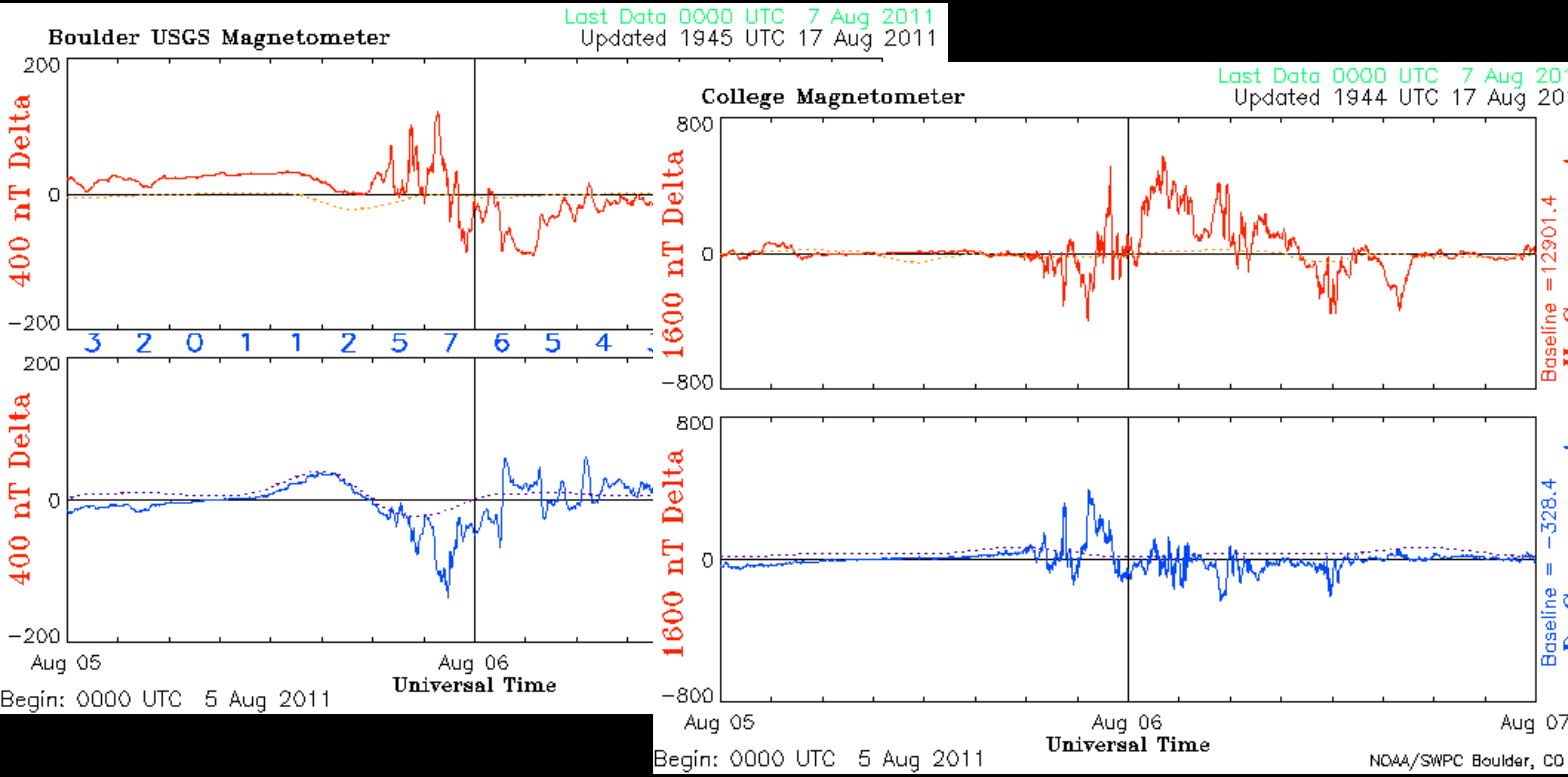
ACE Spacecraft Data 05-08 August 2011



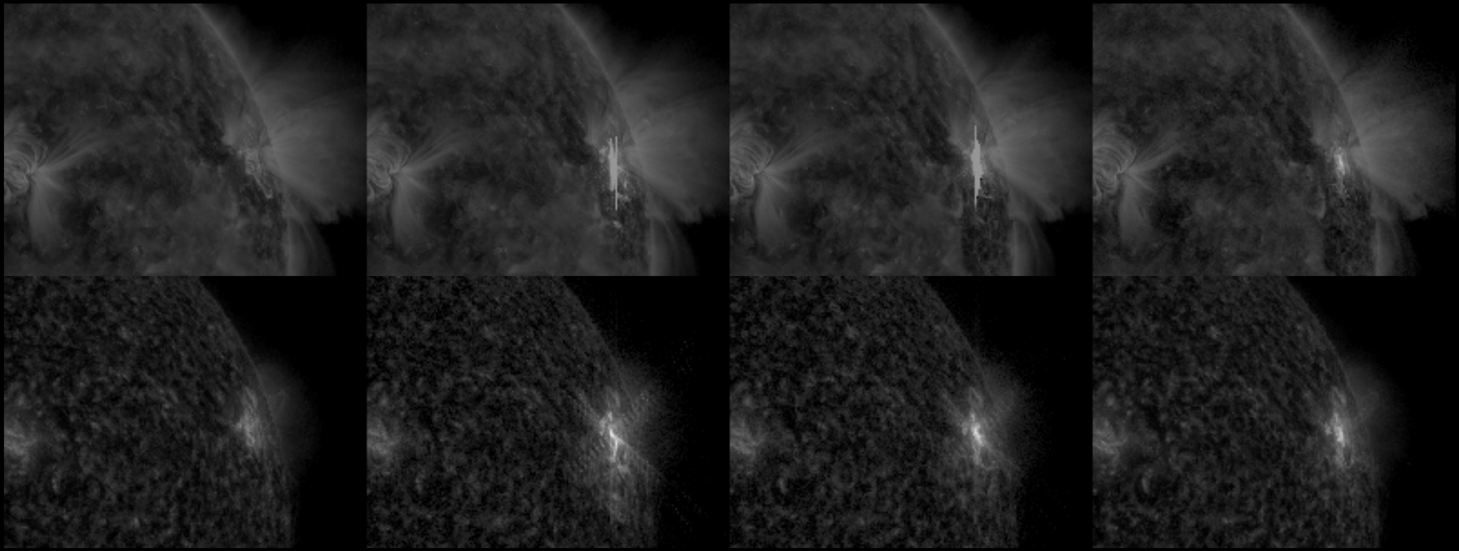
01-08 August 2011 Satellite Environment Plot



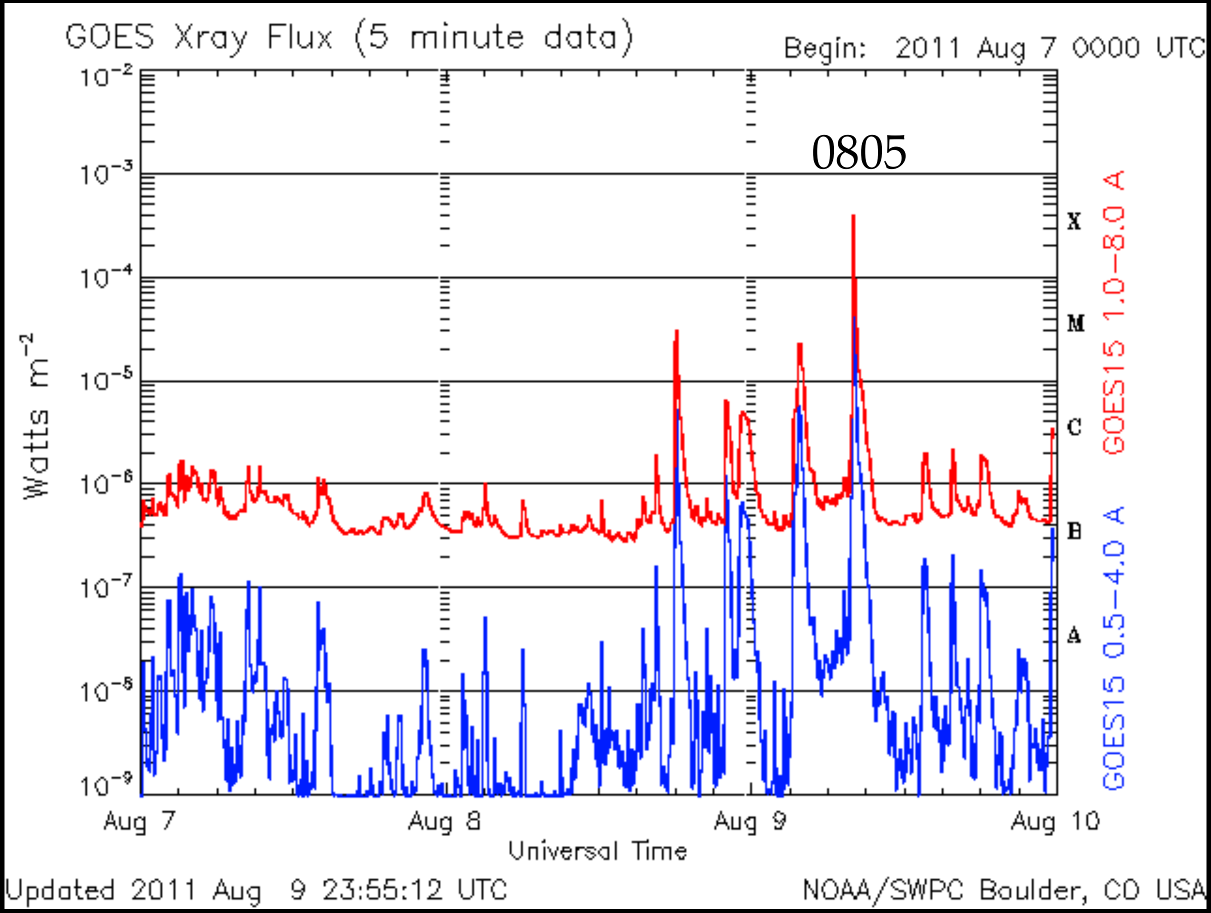
Boulder and College (AK) Magnetometer Plots



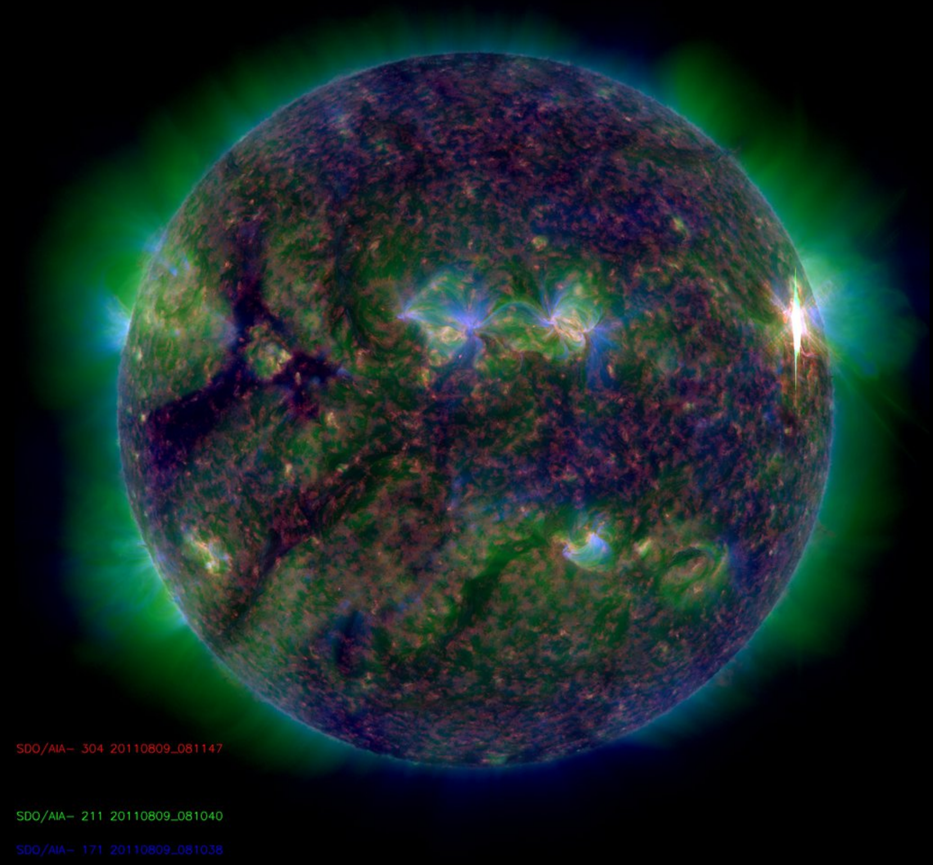
09 August 2011 X7 Flare



09 Aug 2011 X6.9 X-ray Flare



09 August 2011 08:10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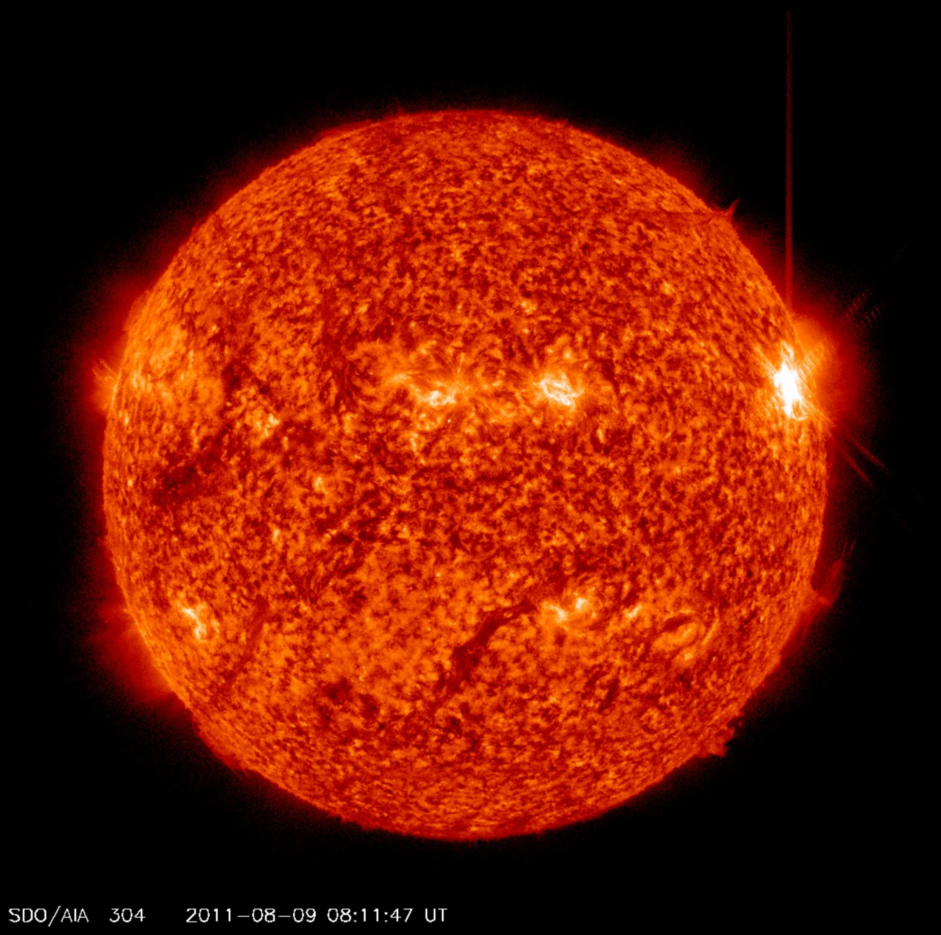
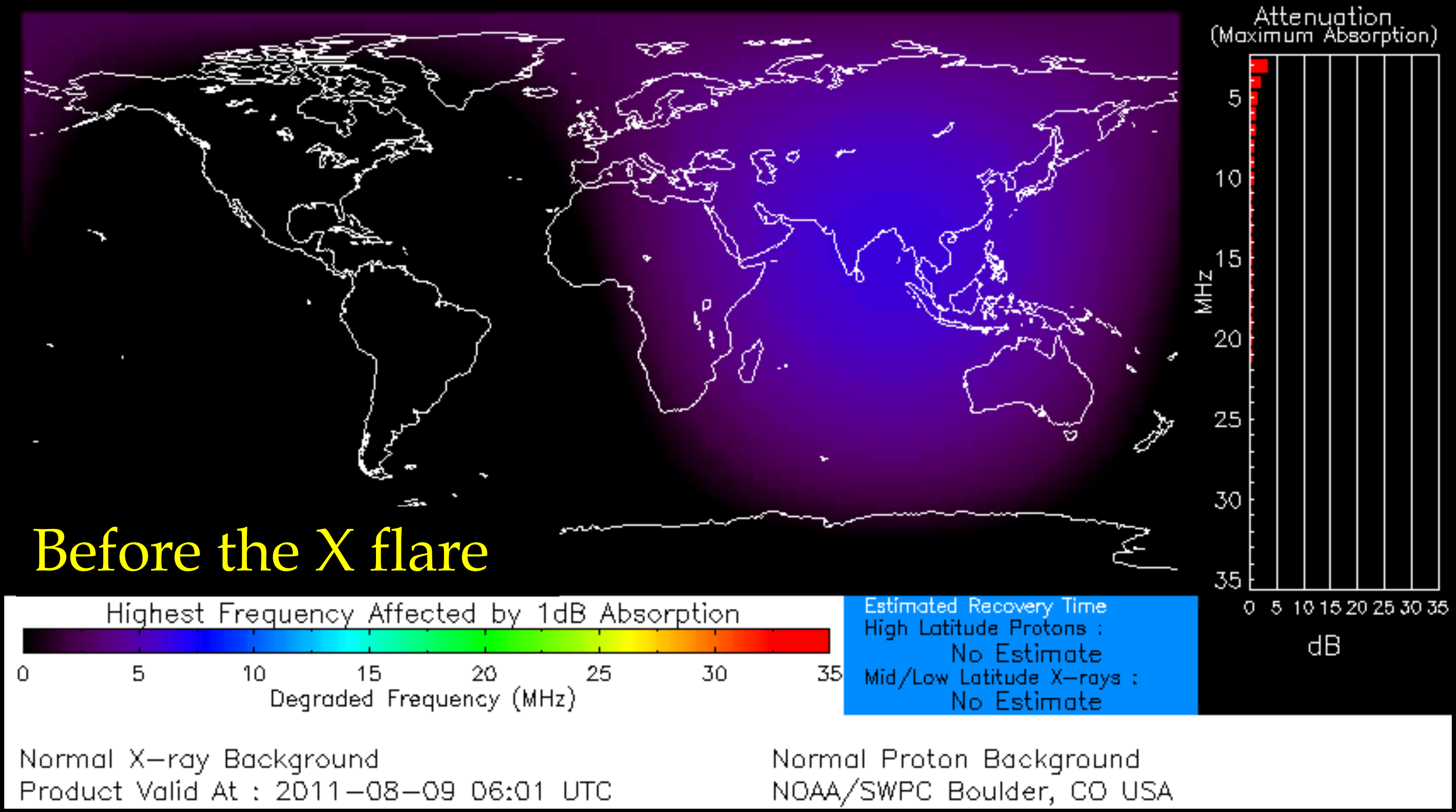
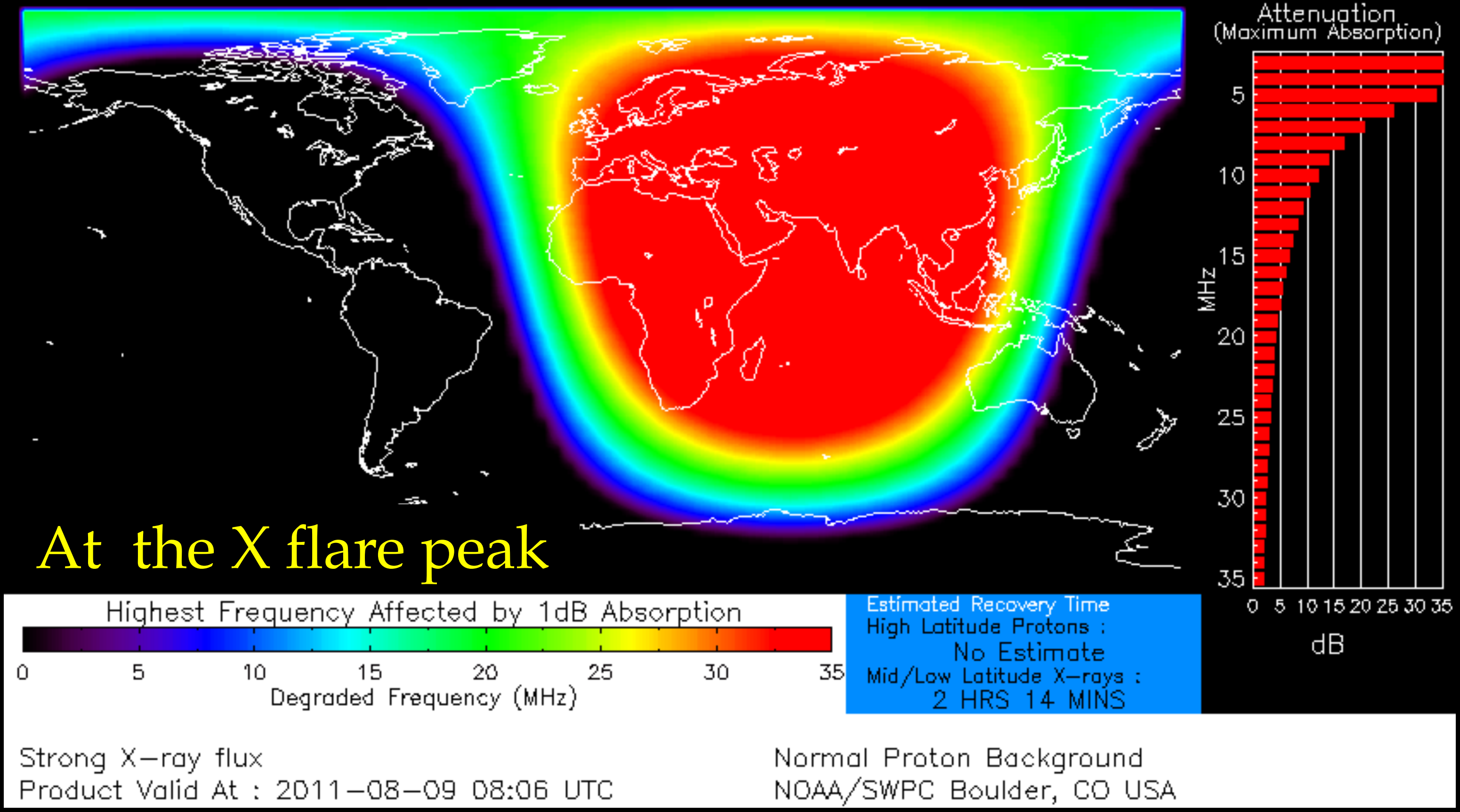
SDO/AIA- 211 20110809_081040
SDO/AIA- 171 20110809_081038



D-Region Absorption Product (D-Rap)


Before the X flare

D-Region Absorption Product (D-Rap)



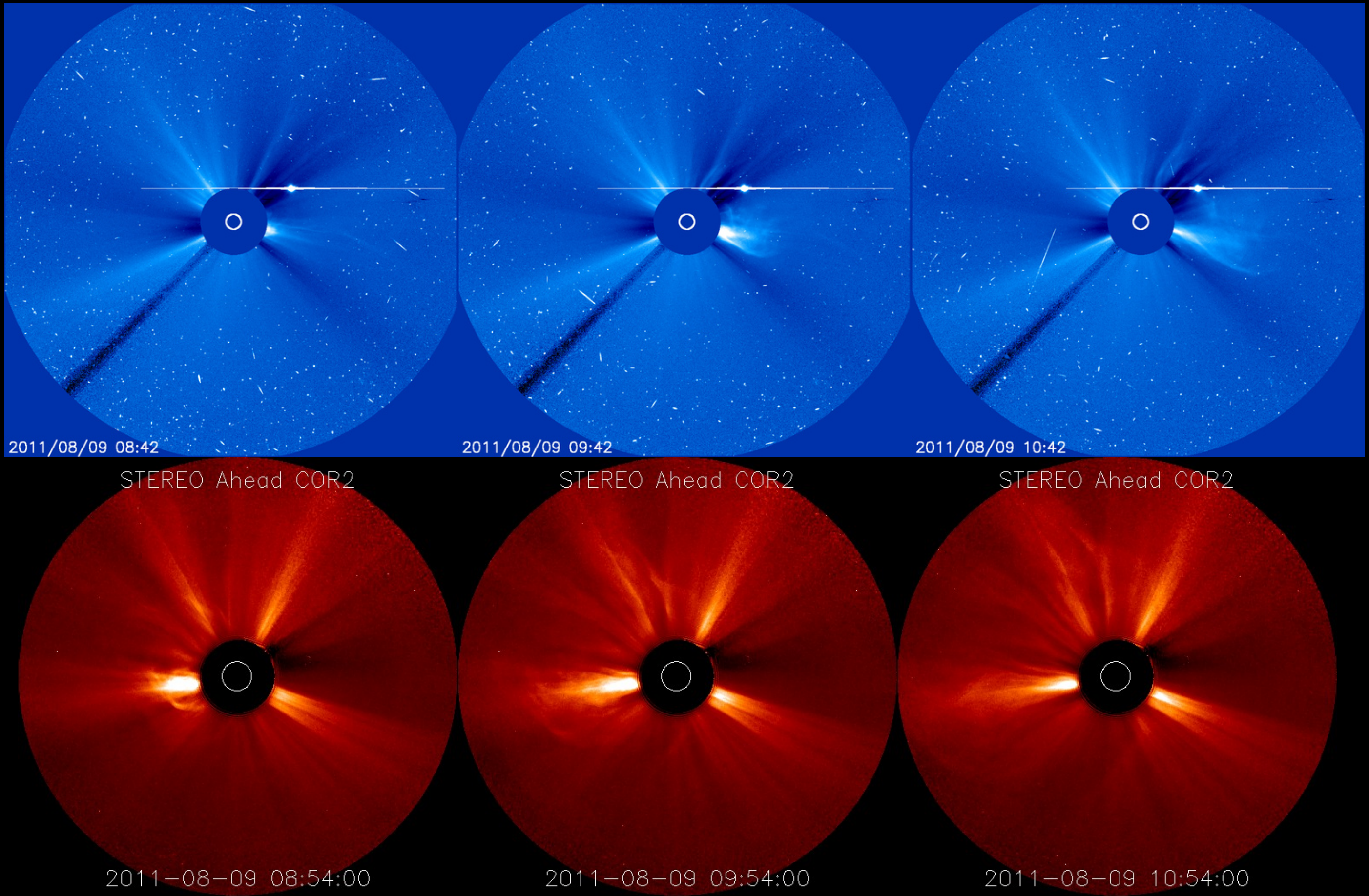
At the X flare peak

Estimated Recovery Time
High Latitude Protons :
No Estimate
Mid/Low Latitude X-rays :
2 HRS 14 MINS

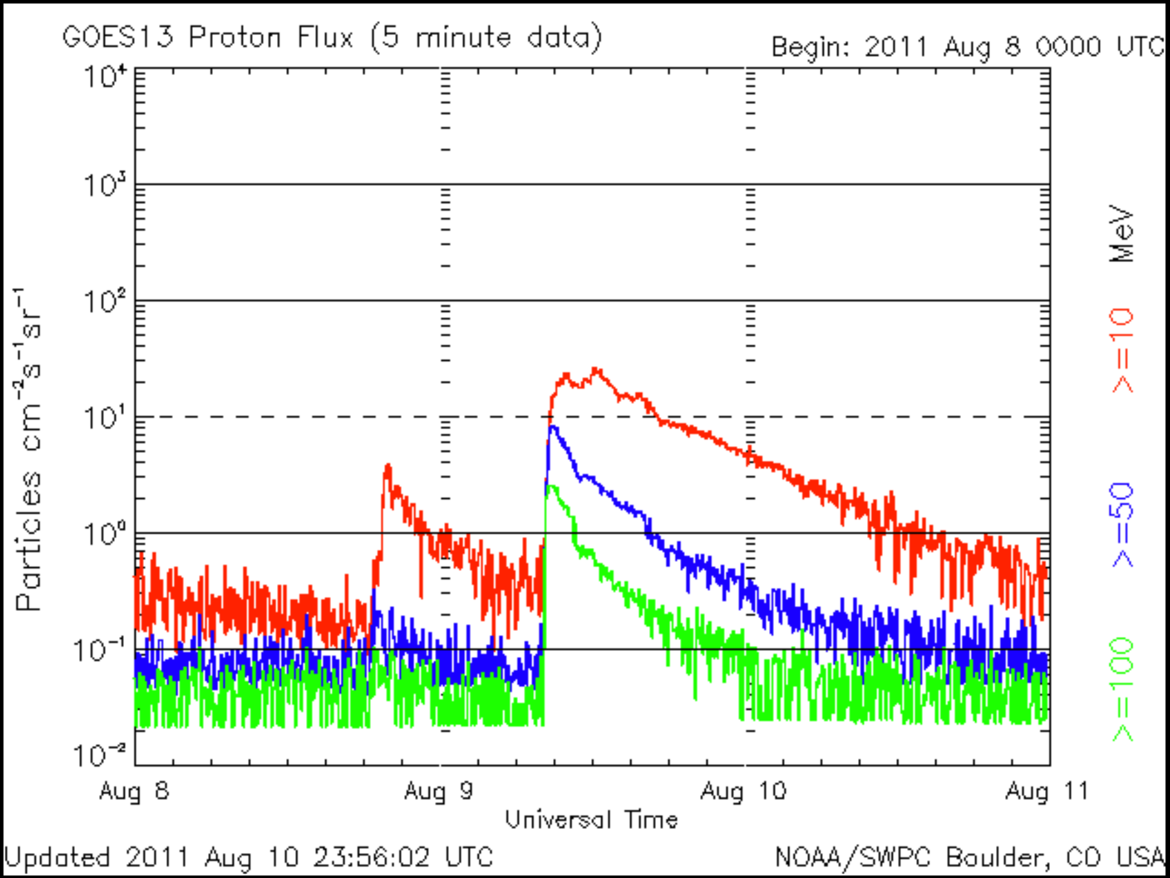
Strong X-ray flux
Product Valid At : 2011-08-09 08:06 UTC

Normal Proton Background
NOAA/SWPC Boulder, CO USA

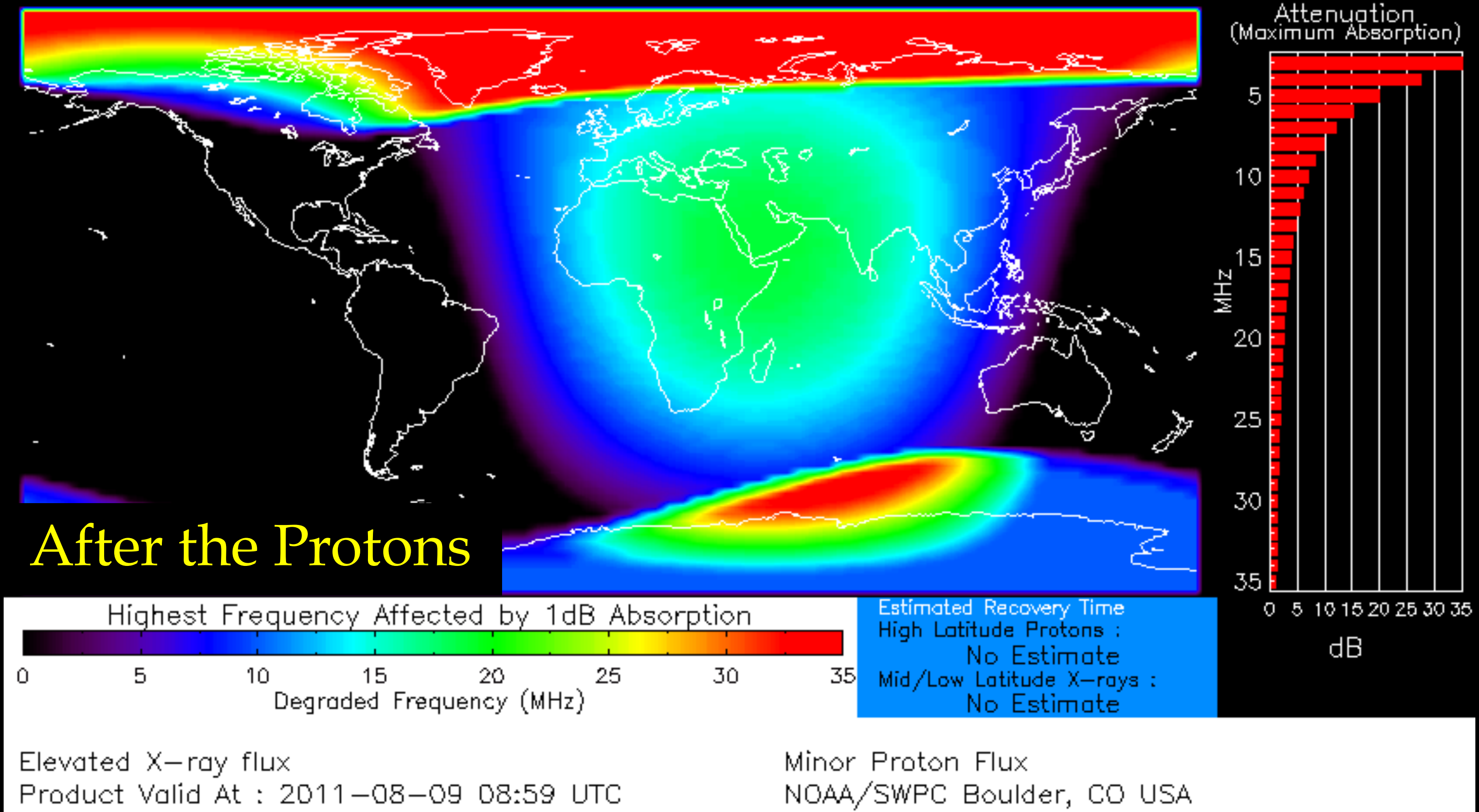
SOHO & STEREO-A Coronagraph



Proton Flux 09 Aug 2011

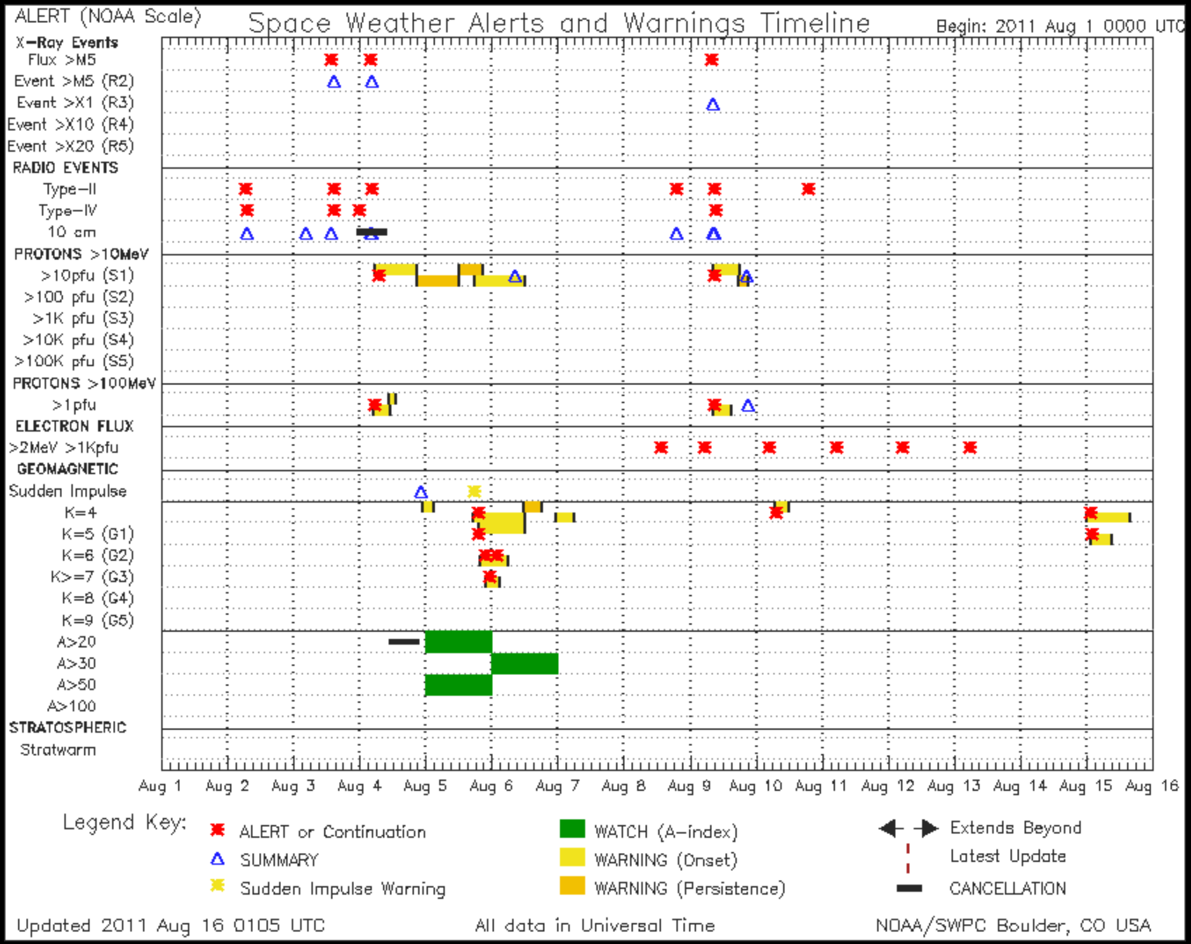


D-Region Absorption Product (D-Rap)



After the Protons

01-15 August 2011 Alerts



Other Useful Links

http://pss.swpc.noaa.gov - Product Subscriptions

http://www.helioviewer.org – Awesome tool for manipulating SDO imagery

http://www.lmsal.com/

http://www.solarmonitor.org

http://iswa.ccmc.gsfc.nasa.gov